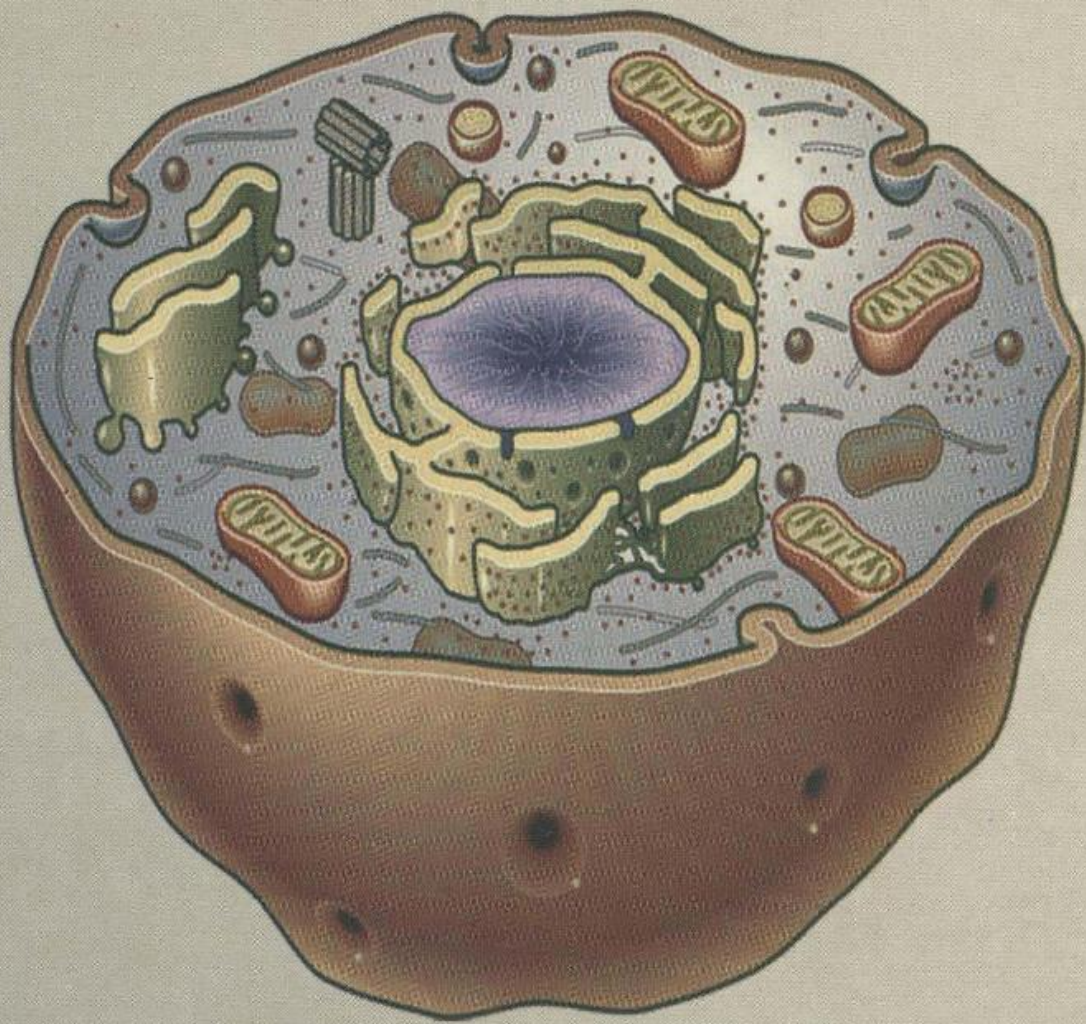


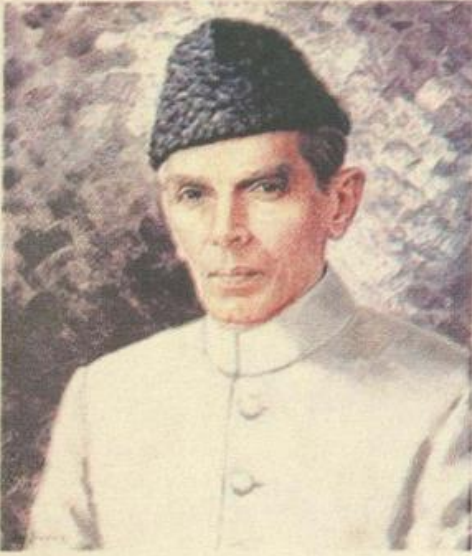
# 10

# BIOLOGY



PUNJAB CHIEF MINISTER'S PROGRAMME  
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(September 26, 1947, Karachi)

Quaid-e-Azam  
Muhammad Ali Jinnah  
Founder of Pakistan

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# BIOLOGY

## X



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# TRANSPORT IN LIVING ORGANISMS

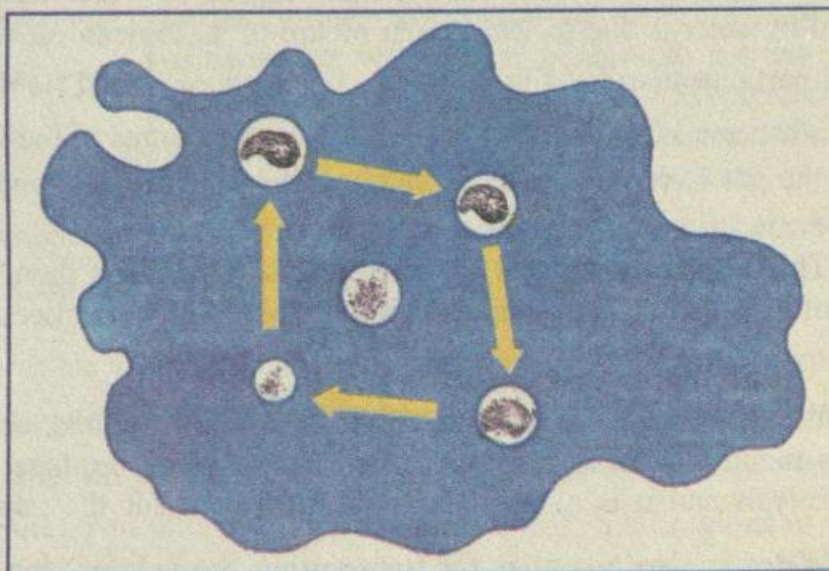
## In this chapter you will learn:

- Importance of water to life.
- Processes involved in transport of material across the cell, diffusion, active transport and osmosis.
- Turgor and its importance in plants.
- Transport of water and salts in plants
- Transpiration and factors affecting it.
- Path of organic material in plants.
- Open and closed circulatory system of animals and circulatory system of man.
- Blood groups and Blood diseases.



In all living organisms plants and animals, physiological processes are continually taking place in their bodies. In order to sustain life, these processes must be kept going on for which the materials required, must be constantly transported to and from all parts of the body right down to the individual cells. Materials are also to be transported between the cell organism and external environment. In unicellular and simple multicellular organisms, the distribution of materials can be adequately brought about by diffusion and streaming movements of the cytoplasm (Fig. 12.1).

However, the evolution of more and more complex body structures necessitated the development of proper transport system, and more complex the organisms are, the more elaborate transport system they have. The complexity of transport system is related to the size and the metabolic rate of the living organism.



**Fig. 12.1 Streaming movement of cytoplasm (in *Amoeba*)**

The materials to be transported are taken close to tissues by the transport system so that diffusion can occur efficiently into the cells. The primary function of the transport system is to maintain a link between all cells of the body and the external environment. It transports the nutrients to the points where they are to be used, facilitates the elimination of metabolic wastes of each cell and transports surplus substances to the specialized storage tissues or to out side their bodies.



## 12.1 Importance of Water to Life

Water is an extra-ordinary compound. It is the only substance that occurs in nature in three phases i.e. solid, liquid and vapour, within the normal range of earth's temperature.

Water is of extreme importance to living organisms. It plays an important role in the sustenance of life as:

- (i) It is an important active constituent of the living matter, the protoplasm.
- (ii) It serves as a metabolite in many metabolic processes.
- (iii) It is a universal solvent and a medium of transport.

### 12.1.1 Water as a Component of Cell

In living cells, water is invariably present. It normally constitutes 85-90 percent of the protoplasm.

However, there are certain structures produced by living organisms, such as seeds, spores, cysts etc. in which the water content may be as low as 10 percent. The reason for the low percentage of water in them is that they are produced under special conditions and are meant for special purpose i.e. reproduction or perennation. They have a very low physiological activity rate, which does not require much water.

Water is present within the cells and also bathes the cells, all around within the body of the organism.

Do you know that the existence of life on our earth is due to the presence of water. If there were no water, life would not have originated or evolved on our earth; no water, no life. Water is not everywhere, but wherever there is water, there is life.

### 12.1.2 Water as a Solvent

Water is an excellent solvent for the substances, which are very important to all processes of life. The salts dissolve to a much greater degree in water than in any other solvent. The solvent potential of water is due to the dipolar nature of its molecules, which causes it to orient itself around charged particles dissolved in it. When, for instance, NaCl (table salt) is dissolved in water, its  $\text{Na}^+$  and  $\text{Cl}^-$  disperse as independent ions. The negative zones of the water dipoles will arrange themselves around the positively charged  $\text{Na}^+$  ions, while the positive zones of the water molecules will do so around the negatively charged  $\text{Cl}^-$  ions.

This alignment of the salt ions in this way keeps them separated and thus promotes a high degree of dissociation. Substances, when dissolved in water, become chemically reactive.

### 12.1.3 Water as a Metabolite

Water acts as metabolite as all the chemical reactions, occurring in the cells, take place in an aqueous medium. Those reactions often consume or produce water molecules. Water is required for hydrolysis and it is also an essential ingredient for the manufacture of food by photosynthesis.

Water is also essential for transporting the solutes, for cooling the plants and animals (by evaporation from their surface), and for developing the internal pressure that provides support and rigidity to the bodies of plants and many animals.

In fact, the life that exists on our earth would not have originated and evolved if there had been no water. The maintenance of constant aqueous internal environment is a principal physiological requirement for all terrestrial as well as aquatic organisms.



## 12.2 Transport of the Materials across the Cells

In the living organisms, each cell is bounded by cell membrane. The cell membranes are able to regulate the movement of materials across them.

The cells constantly exchange materials with their environment through the cell membranes. But the movement of materials, in and out of the cells, across the cell membranes is not an uncontrolled traffic, because certain materials can pass through the membrane, others cannot. Thus the primary function of the cell membranes is to regulate the passage of substances between the interior of the cell and its external environment.

Many different molecules can move across the cell membrane. Of all these, water is the most important one. Many inorganic salts can move across the cell membrane in solution i.e. dissolved in water. One of the processes by which the exchange of materials between the cells and their environment occurs is called **diffusion**. For instance, water and inorganic salts dissolved in it pass into the plants by diffusion through the root hairs into the cells of the roots.

### 12.2.1 Diffusion

It is a process in which the random movement of the molecules or ions takes place down a concentration gradient i.e. from region of higher concentration to a region of lower concentration. Water,  $\text{CO}_2$ ,  $\text{O}_2$  and some other simple molecules can diffuse across the cell-membranes in this way. It is also the main process by which other substances move within the cells. During photosynthesis and respiration in the plants, the exchange of carbon dioxide and oxygen gas, between the cell and the atmosphere also takes place by diffusion. Although diffusion is a slow process, yet it is efficient and rapid enough to fulfill all the gaseous requirements of the plant.

The molecules of some substance because of their size or polarity cannot pass readily, into and out of the cell through the cell membrane. This is brought about by certain proteins called carrier proteins. But here too the movement would be according to the principle of concentration gradient i.e. from higher to lower concentration area. This type of diffusion which takes place with the help of carrier proteins, is called **facilitated diffusion**. Like simple diffusion, in this case also expenditure of energy is not involved.

Diffusion is a well known phenomenon. It can be clearly demonstrated by a simple example i.e. when a coloured crystal like ( $\text{KMnO}_4$ ) is dropped into a bowl of water, initially the color or pigment will remain concentrated at its initial drop area. Gradually its molecules will diffuse evenly in all directions throughout the water, resulting in uniform distribution of color in all regions of the water in the bowl (Fig. 12.2). Similarly, if we spray perfume (air-freshener) in one corner of a room, initially its fragrance will be strongest in that corner and will gradually spread by diffusion in all areas of the room.

The efficiency of diffusion depends on two factors, (a) a distance (b) a concentration gradient difference. The speed of diffusion also depends on the kind of molecules, e.g., diffusion of gases is faster than of liquids; and similarly the diffusion of solids is the slowest.



Diffusion plays a key role in the transport of substances into and out of cell in all living organisms.

### 12.2.2 Active Transport

Sometimes the movement of substances across the cell-membrane takes place against the concentration gradient (uphill movement) i.e. from a region of lower concentration to a region of higher concentration. This type of uphill movement of substances requires the expenditure of energy and is called **active transport**.

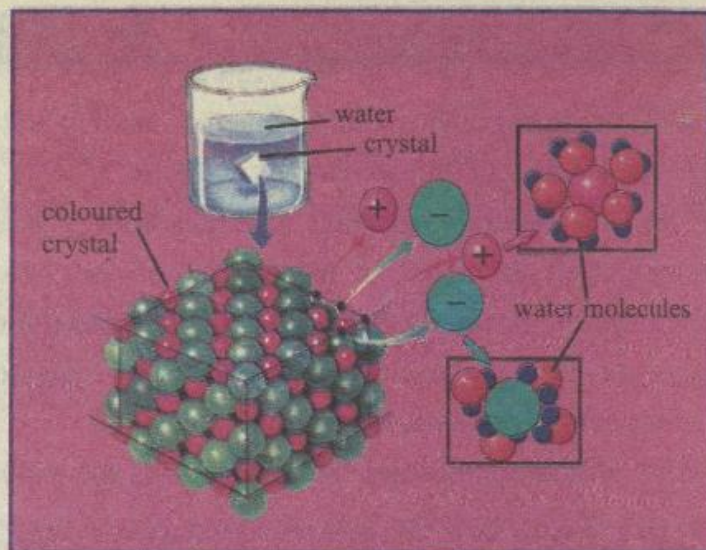


Fig. 12.2. The Process of Diffusion

### 12.2.3 Osmosis

As you all know that a living cell is enclosed in the cell membrane, which allows some substances to pass through it but prevents the passage of others. Such membrane, which is selective in the passage of substances, is called a **selectively permeable** or **differentially permeable membrane**. The solvent molecules, which in most cases are water molecules can readily pass through the cell membrane. The water molecules can easily diffuse through the cell membrane. The movement of water (solvent) through a differentially permeable membrane is a special kind of diffusion called **osmosis**.

#### Practical Work: To Demonstrate Osmosis

Take a thistle funnel and tie a cellophane or egg membrane (both are differentially permeable) around the wide end or the mouth of the funnel. These two membranes are permeable to water molecules but not to dissolved solute molecules such as sugar (sugar).

Fill the thistle funnel, upto a marked level with concentrated sugar solution and place the funnel, with its mouth end immersed in water. You will see that the water would move both into and out of the funnel. But because of the greater water concentration outside the funnel, the movement of water into the funnel would be more rapid than its movement to the outside of the funnel into the beaker. Consequently, the level of sugar solution will rise in the tube of the funnel. As the movement of water into the funnel goes on, the sugar solution in the funnel will become more and more dilute. The movement of water molecules into the funnel was the quickest at the time when it was first immersed into the beaker because at that time there was a concentration gradient greater difference between the water in the beaker and the sugar solution in the funnel. At that time, the movement of water out of the funnel was the slowest. The movement of water into and out of the funnel went on until the equilibrium of water molecules on both sides of the membrane was reached.

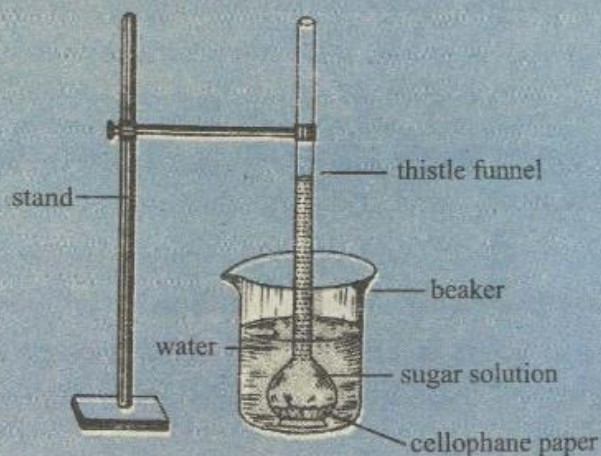


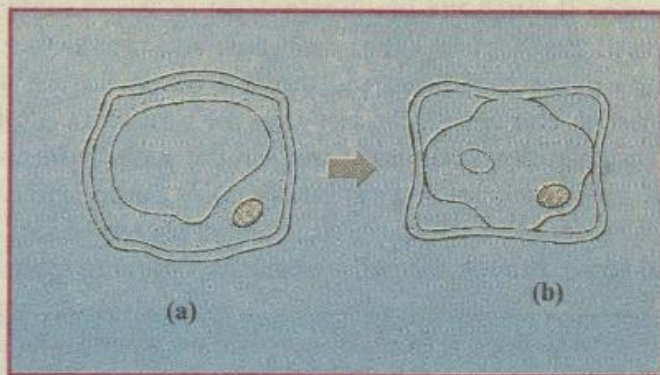
Fig 12.3 Osmosis



## 12.2.4 Turgor

If a cell is surrounded by water or a solution more dilute than its contents (i.e. having lesser concentration of solutes and higher concentration of water), the water tends to move into a cell vacuole by osmosis. As the water enters the vacuole, it increases in size and pushes the cell contents against the wall. The plant cell does not burst as the cell wall is fairly strong and relatively inelastic. However, the cell wall cannot expand beyond a certain limit. The cell wall, thus prevents over-expansion of the cell by exerting an inwardly directed or an opposing pressure which prevents the entry of more water into the cell.

The cell in this state becomes **turgid**. The condition thus produced in the cell is called **turgor** and the internal pressure exerted on the cell wall is called **turgor pressure** (Fig. 12.4a).



**Fig 12.4 (a) A turgid plant cell, (b) The cell begins to become flaccid and wilt**

When all the cells in a leaf and stem are turgid, the plant structures like leaves and young branches will be stiff, firm and upright. If the cells somehow lose water, the cell will lose turgor and will become **flaccid** (soft and limp). The leaves with flaccid cells become limp and the stem droops. Thus plant cells with reduced turgor due to loss of water is said to be **wilting** (Fig. 12.4b).

### Importance of Turgor in Plants

Turgor plays an important role in maintaining the shape of the soft tissues in plants. The movements of certain plant parts also result from the changes in their turgor e.g., changes in the turgor of the guard cells of the stomata cause the opening and closing of the stomata. Some flowers open during the day time and close at night or vice versa. In these the bending movements of their petals is due to changes in turgidity of the cells. The closing of leaves of some plants e.g. touch-me-not, is also due to turgor changes in the leaf-lets.

## 12.3 Transport of Water and Salts

The plants have two types of vascular tissues, namely the xylem and the phloem. The xylem tissue transports water and the dissolved minerals (inorganic salts) from the roots upwards to the stems and the leaves.

Most of the gymnosperms and dicots lack vessels; instead they have tracheids. Each tracheid is an elongated, dead cell with lignified walls, and intact end walls.

The end walls between the vessel element are broken down so that they form continuous, uninterrupted tubes, allowing water to be easily conducted upwards mainly due to transpiration pull, which is discussed later in this chapter.

### 12.3.1 Uptake of Water and Minerals by Roots

Water with dissolved salts enters the plants from the soil through the roots and is then transported to all parts of the plant by xylem. The root hairs, arising just behind the root tip, are outgrowths of the epidermal cells of the root. They enormously increase the surface area for the absorption of water and salts.



The mineral salts are dissolved in the soil water. Much of the water and minerals that enters the root is taken up through the root hairs (Fig. 12.6). The sap water along with dissolved substances moving through the plant or present in the vacuole of the root contains a strong solution of solutes (sugars and various other inorganic and organic salts). Thus a concentration gradient is established between the root hairs and the soil water. So the water from the soil moves into the root hairs by osmosis. The entry of water into the root hairs dilutes its sap. Now the sap of the root hair is more dilute than that of the next cell. So the water from the root hair moves into root cells. The water from the epidermal cells then passes into the xylem vessels and ascends up the stem. This upward movement of water and salts is called **ascent of sap**. Some water travels upwards along the cell walls and some through the cells themselves moving from one cell to another.

### Practical Work: To demonstrate the ascent of sap in plants

Take a medium-sized herbaceous potted plant. Uproot it and place it in a beaker containing red, eosin solution. The roots must be completely submerged in the dye solution. Let the plant stay in the solution for about half an hour. Now cut transverse sections of the stem and leaves from the part of the plant that was out of the eosin solution. Examine the sections under the microscope. You will observe that xylem portions of vascular bundles would have become red by the eosin in the plant. This indicates that water is conducted upward through the xylem vessels in the different organs (Fig. 12.5).



**Fig 12.5. Apparatus showing ascent of sap.**

## 12.4 Transpiration

The xylem vessels of tall trees transport abundant water from the roots to the leaves situated at a height of several meters. What is the force that causes this movement?

Water is the major constituent of plant tissues. The plants absorb large amounts of water from the soil. Of the water absorbed from the soil, only a small proportion of it is retained by the plants while the rest of it is passed off into the atmosphere without being involved in any metabolic activity of the plants, mostly by the process of transpiration.

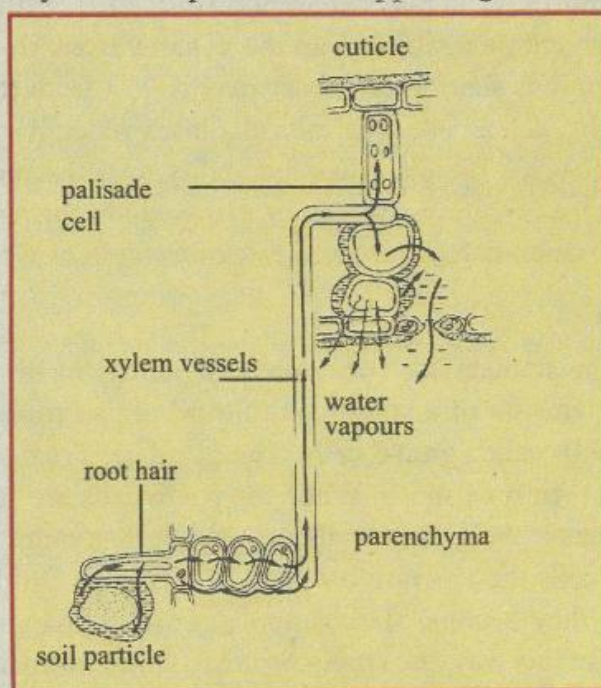
The water absorbed by the roots from the soil enters the root xylem vessels which take it to the leaves. In the leaves, the water leaves the xylem and is distributed to all cells of the leaves but a major percentage of it evaporates from the leaf surface into the atmosphere. So, transpiration can be defined as "the loss of water by evaporation from the aerial parts (cells) of the plant, especially through the stomata of the leaves". As a consequence of loss of water by transpiration, plants require large amounts of water for their survival.

Some of the water entering the leaves diffuses into the cells of the mesophyll tissue of the leaves through their cellulose cell walls (as cellulose is freely permeable to water). The mesophyll cells are in contact with the air-spaces in the leaf. The water from the cells of the mesophyll diffuses through their walls into the intercellular spaces from where it evaporates and diffuses into the atmosphere through the stomata. The evaporation of water from the top of the leaf reduces the concentration of water but increases the concentration of solutes in the leaf cells. So because of



higher osmotic pressure in the leaf cells, more water enters the leaf cells from the xylem. The uptake of water from the top of the xylem, lowers the hydrostatic pressure at upper region of the xylem vessels. Whereas at base of the vessels, this pressure is very high. This difference in the pressure at the base and the top of the xylem vessels produces a pull or tension which pulls the water from the area of high pressure (lower xylem) to the area of low pressure (upper xylem).

The pull or suction force thus produced in the xylem vessels by the evaporation of water (transpiration) from the leaf is called **transpiration pull**. As a consequence of the transpiration pull and the cohesion and adhesion of water molecules, the water moves up the xylem vessels as an unbroken column called the **transpiration stream**. The xylem vessels are a continuous system of tubes from the roots, to the stem and the leaves (Fig 12.6).



**Fig. 12.6. The transpiration stream**

### 12.4.1 Factors Affecting the Rate of Transpiration

The rate of transpiration depends on some environmental factors; such as temperature, wind, humidity, light, atmospheric pressure etc.

#### (i) Temperature and wind

The temperature greatly affects the rate of transpiration. When the temperature is high, rate of evaporation increases, the water molecules move rapidly than at low temperatures and also because warm air can hold more water vapours than the cold air. So, on a warm day the rate of transpiration increases. Windy condition also increase the rate of transpiration as wind removes water vapours from around the leaf and keep the concentration difference high between the leaf and surrounding air.

#### (ii) Humidity

In nearly dry condition or low humidity, the air around the plant will be dry, it will have low concentration of water than that inside the leaves. This difference in the concentration of water would result in an increase in the rate of transpiration. When there is more humidity in air, transpiration would be considerably low, as the air is already saturated with water vapours and it will not be able to absorb more water. So, under such a condition very little water will diffuse out of the leaves.

#### (iii) Light

Light is an important factor in controlling the rate of transpiration as it greatly influences the opening and closing of stomata of leaves. During day-light, the stomata remain open and allow the water vapours from the leaves to diffuse out into the atmosphere. At night or during hours of darkness, the stomata usually close, and the rate of transpiration is greatly reduced or it may even stop completely.

#### (iv) Atmospheric pressure

The atmospheric pressure also affects the rate of transpiration. Reduction in the atmospheric pressure enhances the rate of transpiration.



### 12.4.2 Importance of Transpiration

Transpiration plays an important role in the life of plants as it provides the forces or tension to pull water and mineral ions up the xylem vessels from the roots to the leaves. Sometimes, when the water supply is short, more water may be lost from the plants by transpiration than is absorbed from the soil. In such a condition the plant loses water. As a result of this, the plant loses its turgor and becomes flaccid. The plant has the ability to withstand such a condition if it lasts for a short period. But if such a condition persists for long periods, the plant wilts and even dies. In such conditions many plants have the ability to control the rate of transpiration by closing their stomata.

#### Stomata

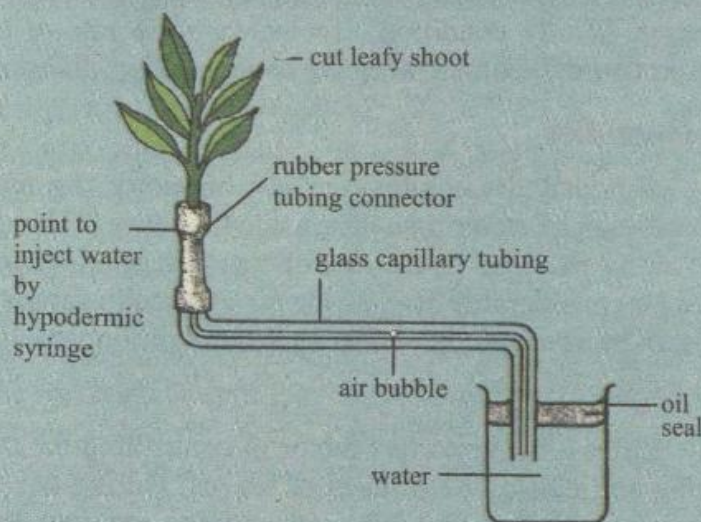
The stomata are very minute openings in the epidermis of the leaves. A stoma (singular of stomata) consists of a small central opening surrounded by a pair of modified epidermal, sausage-shaped, cells called **guard cells**. The guard cells regulate or control the size of the stomatal opening, by changing their own shape. When the guard cells are turgid, their inner margins curve apart from each other because their inner walls are thicker than outer ones. Thus by the curving of the inner margins of guard cells the aperture between them opens. On the other hand, when the guard cells lose their turgidity, they become flaccid and their inner margins become straightened and come to lie close together. In this way, the stoma is closed. If the stomata are closed, transpiration is almost completely stopped.

### 12.4.3 Measurement of the Rate of Transpiration

The rate of transpiration can be measured by many methods. It is generally believed that the rate of absorption of water from the soil is nearly equal to the rate of transpiration. Of the many methods for the measurement of the rate of transpiration, one makes use of a potometer, a glass apparatus that works on the above-mentioned principle.

#### Practical Work: Comparison of the rate of transpiration by potometer

Take a leafy shoot and fix it in one of the arms of a thoroughly water-filled potometer (Fig. 12.7). If there are any air bubbles, these should be excluded. All connections should be made air tight with the help of vaseline or plaster of Paris. Now introduce the air bubble into the capillary tube of the apparatus. Place the setup at a well-lit place. As soon as the transpiration starts, the air bubble will begin to move along the capillary tube, the rate of movement of the air bubble gives the measure of transpiration. Rate of transpiration can be compared under different conditions such as light/shade; under the fan/away from fan etc.

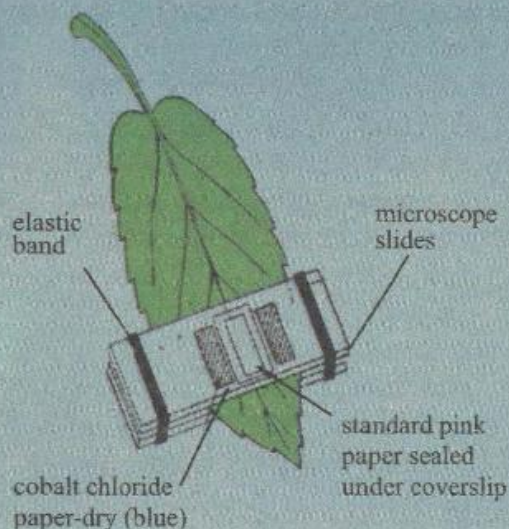


**Fig 12.7. Water potometer for measuring the rate of transpiration.**



### Practical Work: Comparison of transpiration from two surfaces of leaf by cobalt paper

The lower surface of the leaf has more stomata than the upper surface, so more water transpires from the lower surface than the upper surface. This can be demonstrated by the **cobalt chloride method**. In this method the amount of transpiration of water is estimated by the change in colour of the cobalt chloride paper. When dried cobalt chloride paper is exposed to humid air or moisture it will gradually change its colour from blue to pink. The normal colour of dry (anhydrous) cobalt chloride paper is blue. The cobalt chloride paper can be prepared by treating filter paper disc with 3% slightly acidic solution of cobalt chloride. After treatment the filter paper discs are thoroughly dried. In order to perform this experiment, take two equal sized discs of blue cobalt chloride filter papers. Place one disc on the upper and one on the lower surface of the leaf of a potted plant. You will see that after a few minutes, the cobalt chloride paper starts changing colour from blue to pink. You will note that the paper fixed on the upper surface of the leaf takes much longer time to turn pink from blue than that of the paper on the lower surface of the leaf. The rate of change of colour indicates the rate of transpiration, which is much higher from the lower surface than from the upper surface. This is because of the presence of stomata on the lower surface (Fig. 12.8).



**Fig 12.8. Cobalt chloride paper**

## 12.5 Path of Transport of Organic Materials in Plants

The green plants manufacture food in the leaves. From the leaves, the sugars need to be moved to the non-photosynthetic parts of the plants such as roots, stems and flowers for storage or consumption.

The manufactured food substances (sugars) are transported from the leaves to the other parts of the plant body by phloem tissue (mainly sieve tubes) as its structure is well suited for this function.

The transport of carbohydrates, mostly in the form of sucrose (sugar), from the leaves to all other parts of the plant is called **translocation**. In addition to sugars, the phloem also transports amino acids, growth hormones, and vitamins.

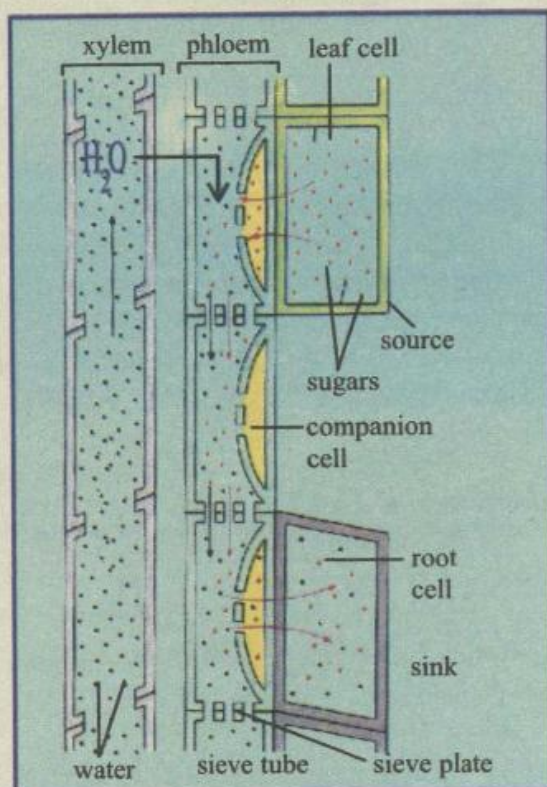
The mechanism of the translocation of these substances through the sieve tube cells of the phloem is not yet clearly understood. Several hypotheses have been proposed to explain this mechanism. One of these hypotheses is the **mass flow hypothesis** (Fig. 12.9). Many plant physiologists favour this hypothesis.

According to the mass flow hypothesis, the sugars in solution can move freely through the sieve tubes from the leaves to all non-photosynthetic parts of the plants. This movement is because of the difference in the concentration gradient at the place of manufacture of sugar i.e., the leaves and the other parts of the plant which need nourishment to carry out their activities. As the food is manufactured in the leaves, the sieve-tubes in their veins are loaded with sugar. More water therefore enters then by osmosis. Consequently they have a high sugar pressure. Other parts of the plant



have low concentration of sugar and consequently low sugar pressure. So the sugar will move from a region of high concentration(source) to the region of low concentration(sink).

The phloem stream, carrying the manufactured food, moves in the direction opposite to that of the transpiration stream. One objection against the mass flow hypothesis is that the phloem often transports substances in the opposite direction too i.e., up the stem to provide nourishment and energy to the leaves and shoots for their growth and also to the developing seeds and fruits. But this objection to the mass flow hypothesis does not hold good if we recall the structures of the phloem tissue. The phloem tissue consists of many sieve tubes, not just one, and the fluids can move in opposite direction in two different but closely situated sieve-tubes. Here too, the movement of fluids in opposite direction would also depend on opposing pressure gradients in the two ends of the sieve-tubes.



**Fig. 12.9 Pressure flow hypothesis.**

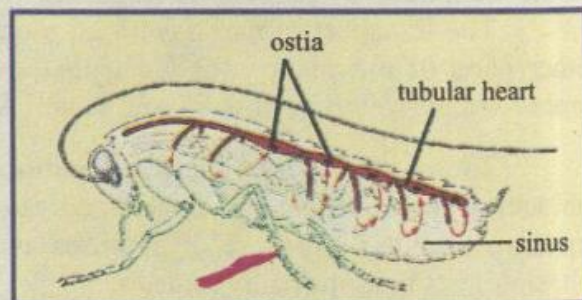
## 12.6 Transport in Animals

As you have already learned that in all living beings the nutrients and gases are transported to and from all parts of the body. This is essential to carry on various life processes. In case of unicellular and small multicellular organisms transport takes place by diffusion. However, in large multicellular organisms, as the distances between different body parts have increased, they need an elaborate and efficient system for transportation of materials. In large animals, such a system is called **circulatory system** in which a fluid circulates in all parts of the body. In many invertebrates this fluid is the **haemolymph**, whereas in all vertebrates and in some higher invertebrates this fluid is the blood.

The circulatory system in animals is of two main types (A) open circulatory system and (B) closed circulatory system.

### (A) Open Circulatory System

Many invertebrates e.g. arthropods have open circulatory system [Fig 12.10(a)]. In this system the blood is pumped from the heart into the blood vessel. The blood vessels in turn, empty themselves into open spaces called **sinuses**. In the sinuses, the blood is in direct contact with the tissues, and after exchange of materials with the tissues it re-enters the heart for circulation again.



**Fig. 12.10(a) Circulatory system in insect**

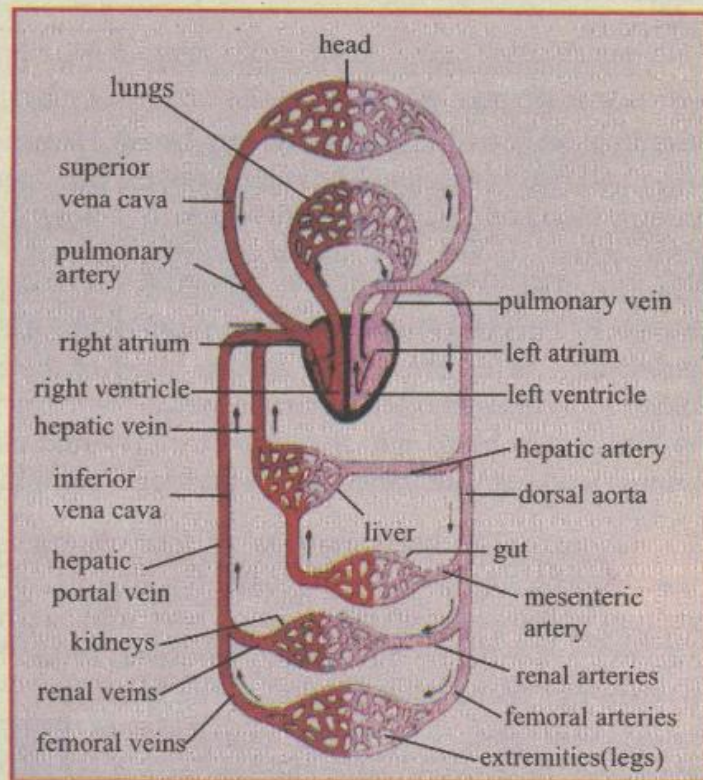
### (B) Closed Circulatory System

Closed circulatory system is more elaborate, complicated and efficient as compared to the open circulatory system. The closed circulatory system consists of a muscular, and contractile pumping



organ, the heart with its incoming (veins) and outgoing (arteries) blood vessels. The blood remains confined in the blood vessels while circulating in the whole body e.g. earthworm, man etc.

In closed circulatory system, the heart pumps blood into the blood vessels (arteries) which take away the blood from the heart to the tissue. In the tissues, the arteries divide and subdivide into very fine branches, called the capillaries. The walls of capillaries are just one cells thick, and in them the blood is in close contact with the tissue cells. Exchange of materials with tissues is carried out here. The capillaries join and form bigger blood vessels called venules. These venules in turn join to form the veins, which ultimately transport blood back to the heart. (Fig. 12.10 - b)



**Fig. 12.10(b) A general plan of close circulatory system .**

### 12.6.1 General Plan of Circulatory System of Vertebrates

In vertebrates, the circulatory system is always of closed type. The closed circulatory system is further of two types, (a) single circuit circulation, (b) double circuit circulation.

For instance in fishes the circulation is of single type. In it, only the deoxygenated blood circulates through the heart. The deoxygenated or the venous blood from all tissues of the body enters the sinus venous, from where it passes into the single auricle or atrium. From the atrium it goes in the ventricle. From the ventricle, the blood is pumped into the gills for oxygenation. The oxygenated blood from the gills is directly distributed to all parts of the body. As the blood circulates once through the heart, therefore, this type of circulation is called **single circuit circulation**.

In land vertebrates, with the introduction of lung respiration, **double-circuit circulation** evolved. The evolution of double circuit circulation led to the division of atrium and ventricle, each into two chambers. The atrium divided into right and left atria (plural of atrium) and likewise the ventricle also divided into two chambers. In amphibians, the ventricle is not divided and in most reptiles, the division of the ventricle is incomplete. In some reptiles and in all birds and mammals, the division of the ventricle is complete. So in these animals, oxygenated and deoxygenated bloods are completely separated from each other and there is no mixing of these two types of blood. This increases the efficiency of the circulatory system. The circulatory system in vertebrates is highly developed and among them mammals have the most efficient circulatory system.

### 12.6.2 Human Blood Circulatory System

The human blood circulatory system, like other vertebrates, consists of a heart, a system of blood vessels and blood. Study it in your class using a model of human heart.



## Structure and Action of Heart (Human Heart)

The human heart like other vertebrates is a muscular, contractile structure. The cardiac muscles of the heart are capable of strong contraction which brings about the circulation of blood through out the body.

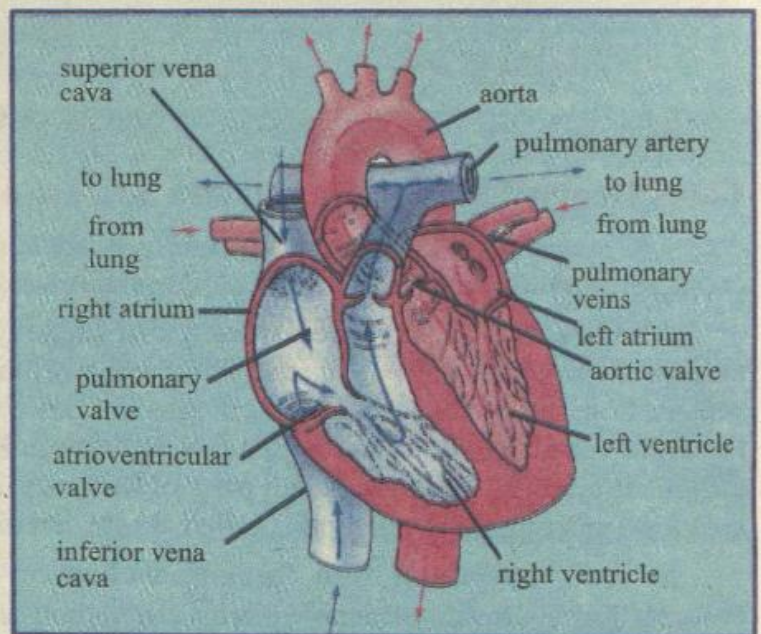
The mammalian heart (including that of man) is two pumps in one. The mammalian heart has four chambers-two atria and two ventricles. The right atrium pumps blood into right ventricle which in turn pumps blood into the pulmonary arteries. From lungs the oxygenated blood is carried to left atrium through pulmonary vein. From left atrium the blood is pumped into left ventricle which in turn pumps blood into the aorta- the **systemic circulation** (this is pump two). Thus there are two pumps working simultaneously in the single pumping organ-the heart.

### The Heart Bag- The Pericardium

Heart is enclosed in a tough, fibrous bag. This bag is the pericardium. Between the pericardium and the heart is a fluid called pericardial fluid which acts as shock absorber and protects the heart from the external shocks. The pericardium is not flexible or extensible. It also probably limits the over-extension of the heart in certain extreme conditions.

The heart consists of four chambers. The upper half of the heart consists of two independent, thin walled chambers, the atria or auricles separated from each other by a partition or septum called **inter atrial** or **inter auricular septum**. The right atrium receives the deoxygenated i.e., oxygen deficient blood from all tissues of the body whereas the left receives the oxygenated or oxygen-rich blood from the lungs. The lower half of the heart consists of two thick walled chambers called ventricles, which are completely separated from each other by an inter-ventricular septum. Ventricles are much larger than the atria and are involved in pumping the blood out of the heart.

The inter-atrial and inter-ventricular septa (singular: septum) prevent the mixing of deoxygenated and oxygenated blood. Each atrium pushes the blood into the ventricle of its side through an atrio-ventricular aperture. The atrio-ventricular apertures are guarded by valves, the atrio-ventricular valves. These are made of almost transparent, thin but very tough flaps of tissue. The right atrio ventricular valve consists of three cup like flaps and is called **tricuspid valve**, while the left consists of two cup like flaps and is called **bicuspid valve**. The atrio-ventricular valves allow the flow of blood from the atria to the ventricles but at the time of ventricular contraction, they prevent the backward flow of blood from the ventricles to their respective atria (Fig. 12.11).



**Fig. 12.11 Internal structure of heart and the directions of flow of blood.**

The two atria contract simultaneously to push blood into ventricle. On the other hand, the ventricles have to contract with a great force as they have to push the blood to the lungs and to the rest of the body. The left ventricle contracts more forcefully than the right one, as it has to push the blood all around the body, while the right one has to push the blood to the lungs which are fairly close to the heart.

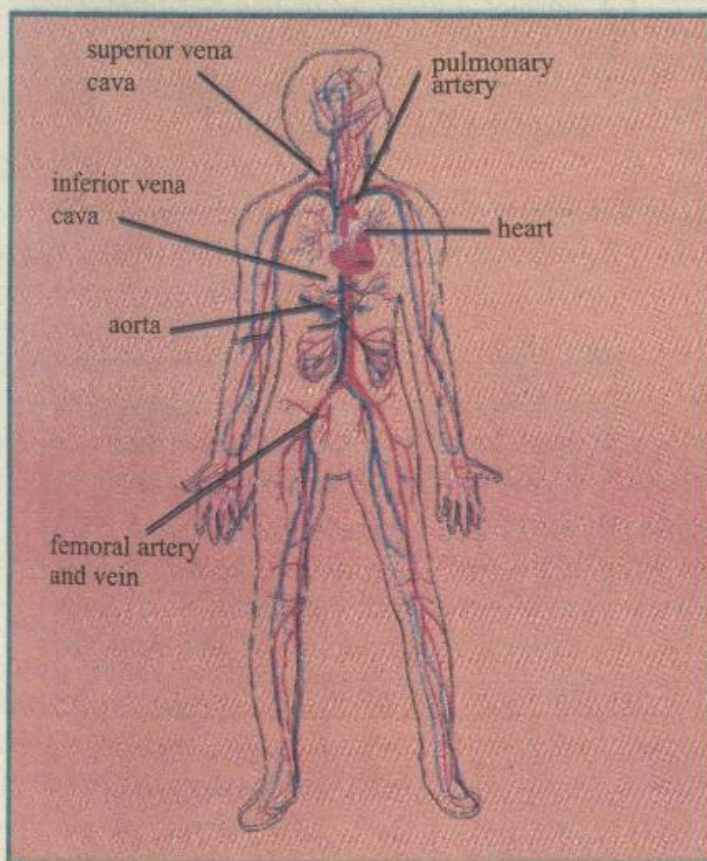


## Pulmonary Circulation

The left atrium receives oxygenated blood from the lungs through a pair of **pulmonary veins**, which open into the left atrium. From left atrium, the blood flows into the left ventricle. The right atrium which receives deoxygenated blood from all parts of the body, empties itself into the right ventricle. From there the blood is passed into the lungs, for oxygenation, by a pulmonary arch, which divides into two pulmonary arteries, each going to the lung of its own side. The opening of the pulmonary arch and the aorta, into the left and the right ventricles respectively are guarded by two semilunar valves. At the time of contraction of ventricles, semilunar valves allow the blood to enter the pulmonary arch and the aorta and when the ventricles relax, prevent its backward flow into the ventricles. This part of the circulatory system is called pulmonary circulation. It must be noted that in pulmonary circuit, the pulmonary arteries carry the deoxygenated blood. While the pulmonary veins carry the oxygenated blood.

## Systemic Circulation

From the left ventricle the systemic arch or the aorta originates. The aorta distributes the oxygenated blood to all parts of the body through a number of blood vessels (arteries). Near the proximal region of the aorta, arise the carotid arteries which supply blood to the head and the face. A pair of subclavian arteries from the aorta supplies blood to the shoulder region and the arms.



The alternating contraction and relaxation of the heart chambers is called the cardiac cycle. The two atria contract simultaneously emptying blood into ventricles. A fraction of a second later, the two ventricles contract simultaneously forcing blood into arteries leaving the heart. Both the ventricles then relax briefly before the cycle is repeated. The period of ventricular contraction is called **systole** and their relaxation is called **diastole**.

In mammals (including man) the heart receives its blood supply through a pair of coronary arteries which arise from the aorta close to its origin. The coronary arteries break up into an extensive network of capillaries surrounding the cardiac muscles and provide them the oxygen and the nutrient.

**Fig. 12.12 Blood Circulation in Man**



In the region of the liver, the aorta gives off a hepatic artery which supplies the oxygenated blood to the lobes of the liver. The kidneys receive their blood supply through a pair of renal arteries arising from the aorta. In the gut region, the aorta gives off a mesenteric artery to supply blood to the digestive tract (Fig 12.12).

The deoxygenated blood from the head and the shoulder region is collected by jugular and subclavian veins which join together to form a large vein, the superior vena cava. The superior vena cava pours its blood into the right atrium. From the hind limbs, the deoxygenated blood is collected by a pair of iliac veins, which join together to form the inferior vena cava. The inferior vena cava on its way forward towards the heart receives a pair of renal veins. The deoxygenated blood from digestive tract is collected by a number of veins which join together to form the hepatic portal vein, which opens into the liver and pours its blood there. From the liver, the deoxygenated blood is collected by a hepatic vein, which opens into the inferior vena cava.

## Composition of blood

Blood is a fluid connective tissue, which circulates throughout the body. It transports oxygen and nutrients to all parts of the body, down to the individual cells and brings back the waste products of metabolism from all over the body. It consists of a fluid portion, the **plasma** and the blood cells. **Erythrocytes** (red blood cells), **leucocytes** (white blood cells) and **thrombocytes** (platelets), are suspended in the plasma. Plasma minus **fibrinogen** (blood clotting protein), is called serum.

A normal human adult has 6-7 litres  $\pm$  1 litre blood, of which 55% is plasma i.e. 3.70 litres  $\pm$  0.55 litres and 45% are blood cells i.e. 2.55 litres  $\pm$  0.45 litre.

## Plasma

Plasma is a very complex fluid, which consists of about 90% water, and 7-8% proteins (albumins, globulins & fibrinogen). 2-3% of plasma contains glucose, amino acids, lipids, enzymes, hormones, antibodies and traces of many organic and inorganic materials including dissolved gases.

The normal average number /mm<sup>3</sup> of erythrocytes in persons living at high altitudes i.e. hilly areas is much higher than those living in plain. The average number of erythrocytes in these persons is nearly 7 million/mm<sup>3</sup>. Do you know why this is so? The reason is that at high altitudes the oxygen is lower than the plains. So in order to meet out the oxygen requirements of the body the number of erythrocytes becomes high.

## Blood Cells

The blood cells are of three types.

- (i) Erythrocytes or Red Blood Cells (**RBCs**)
- (ii) Leucocytes or White Blood Cells (**WBCs**)
- (iii) Thrombocytes or Platelets



## Erythrocytes or Red Blood Cells

In a normal human individual their number on the average is approximately 5 million / mm<sup>3</sup> of blood. In birds and mammals, the erythrocytes are produced in bone marrow. In mammals the mature erythrocytes lose their nucleus, mitochondria, Golgi bodies, and endoplasmic reticulum. They have biconcave disc-like shape. In all other vertebrates, the erythrocytes are nucleated and have an oval or ellipsoidal shape. The primary function of erythrocytes is to transport gases. The erythrocytes contain hemoglobin which is the respiratory pigment. It transports oxygen, from the lungs to other tissue of the body, and transports carbon dioxide from the tissues to lungs.

### Practical Work: Study the blood smear under microscope.

1. Place a drop of anticoagulant like 1% sodium citrate solution on the slide and add a drop of fresh blood of chicken in the anticoagulant.
2. Spread the blood smear on the slide with the help of another slide edge.
3. Dry the spread for few minutes and observe under the microscope.
4. Draw the blood cells seen and compare it with the cells that you have studied.
5. Do not use blood or cheek smear from students, it may lead to serious consequences like contraction of aids and hepatitis.

## Leucocytes or White Blood Cells

These cells are colourless and larger in size than the erythrocytes. They are nucleated and motile cells. These cells are of several types such as neutrophils, monocytes, lymphocytes, eosinophils and basophils, which differ in structure and also in function. White blood cells defend the body from disease by engulfing and destroying germs and by producing antibodies. The total number of all these kinds of leucocytes is much less than the erythrocytes. In human beings their number ranges from 5000 to 7000 / mm<sup>3</sup> of blood.

## Thrombocytes or Platelets

In mammals (including man), the blood in addition to erythrocytes and leucocytes contain platelets. The platelets are not complete cells (Fig. 12.13). They are minute and non-nucleated cell fragments. Their number in the circulating blood ranges between 150,000 to 350,000 / mm<sup>3</sup> of blood. They play an important role in blood clotting and are essential for it.

## Blood pressure

Blood pressure is the pressure per unit area, which the flowing blood exerts on the walls of the blood vessels. In human beings, the blood pressure is measured at the artery of the upper arm. The measurement of blood pressure indicates the higher or systolic blood pressure and the lower or diastolic pressure. In normal

young adults the systolic blood pressure is 120 mm Hg and the diastolic pressure is 80 mm Hg. Thus the normal blood pressure is expressed as 120/80 mm Hg.

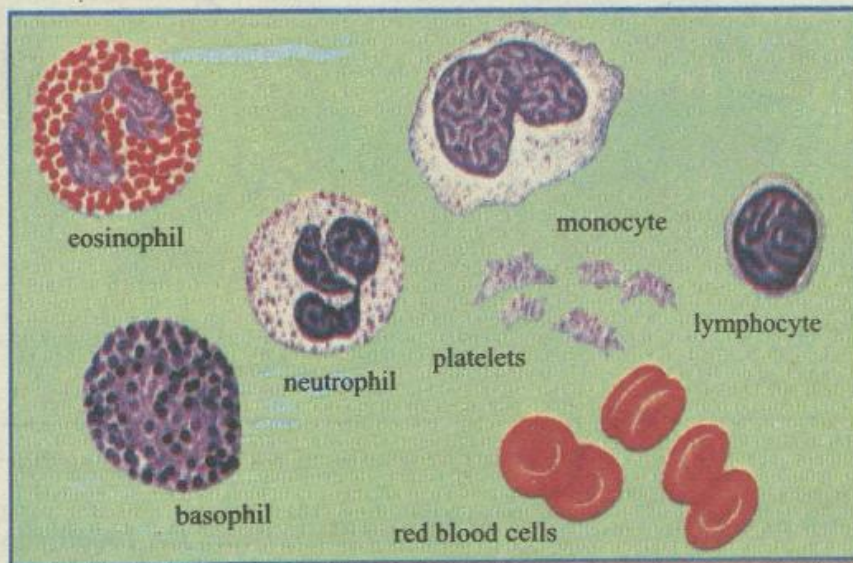


Fig 12.13 Blood cells



## 12.7 Blood Vessels

In vertebrates there are three kinds of blood vessels, arteries, veins and capillaries. These vessels differ from each other in the structure of their walls, which is related to their functions.

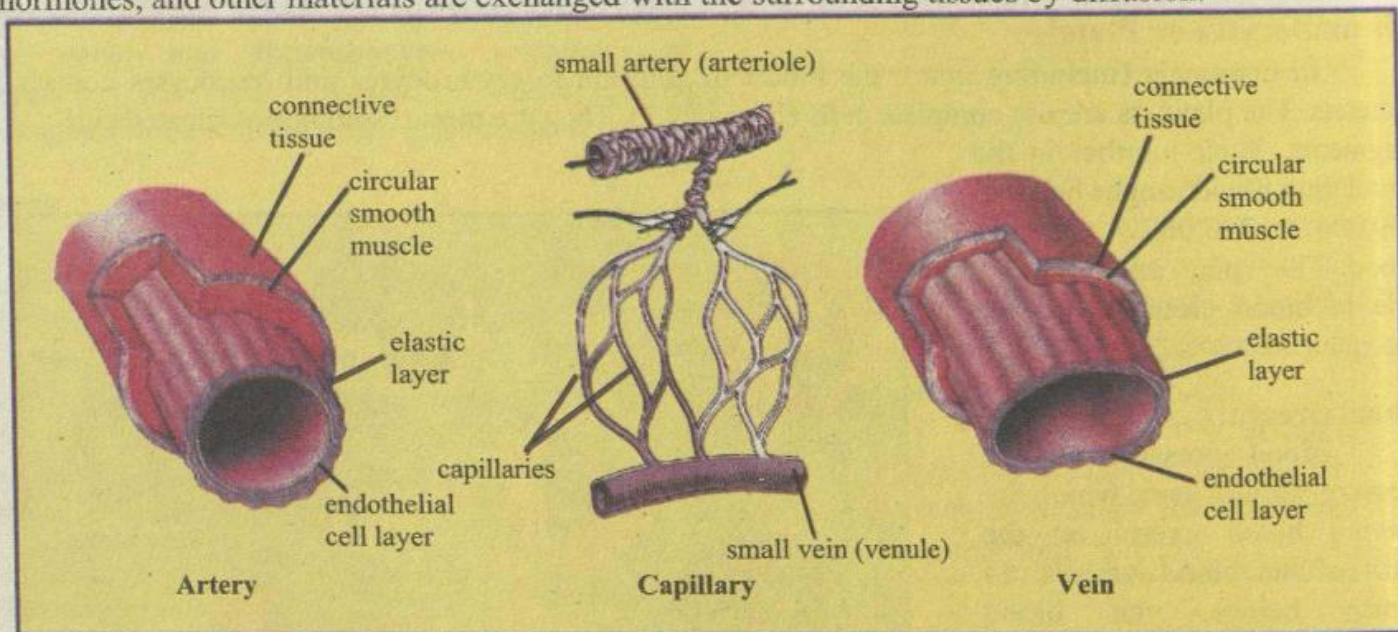
### Arteries

Arteries are the vessels which have to carry blood from the heart to all tissues of the body. The structure of the walls of the arteries is related to their function. They have the strongest and the thickest walls. The arterial walls are made up of three layers. The innermost layer, forming the lining of the inner surface of the arterial wall, is called **endothelium**. The middle layer consists of smooth muscles and **elastic tissue**. The outermost layer is also elastic and consists of **connective tissue**. Because of their elastic walls, the arteries are stretched when the blood enters them and then recoil slowly. Thus the blood in the arteries is 'pulsing' and the pressure in them fluctuates with the heart beat. You can feel the pulse if you place your fingers on an artery in the neck or the wrist. Because of their strong and elastic walls, the arteries are able to withstand the high pressure of blood in them.

The arteries, on reaching closer to the tissues, divide into arterioles. The arterioles, on entering the tissues, further divide into very fine branches, the capillaries.

### Capillaries

The function of the capillaries is to deliver the blood as close to all the body cells as possible. The walls of capillaries are extremely thin, consisting of only a single layer of cells, the endothelium. The lumen of the capillaries is so narrow that the erythrocytes can move through them only in a single file. As the blood moves through the capillaries, the gases (oxygen and carbon dioxide), hormones, and other materials are exchanged with the surrounding tissues by diffusion.



**Fig 12.14. Structure of an artery, a capillary and a vein.**

### Veins

At the venous ends of the capillary beds, the blood flows back in slightly thicker vessels, called the **venules**. The venules join together to form larger vessels, the veins, which ultimately transport the blood from the tissues back to the heart. The walls of the veins, like those of the arteries, are also three-layered but they are less elastic and more pliable. The walls of the veins are thin and



almost inelastic, that an empty vein collapses, whereas empty artery does not collapse (Fig. 12.14). Veins are provided with valves to check backward flow of blood.

### **Practical Work: Study the blood circulation in a fish tail or a frog's web or fish tail**

1. Take the live specimen (frog or fish). If frog is selected pith it and then spread its web in the hind limb. Hold it in two slides and keep it at a place with a proper clip or thread. For fish keep wet cotton on gills for respiration and spread the tail as described in frog's web study.
2. Place it under the microscope and study the blood circulation.
3. How blood moves in capillaries? Draw a label.

### **Tissue Fluid**

We have already learnt that capillaries reach closest to the tissues of the body and carry the blood to all tissues of the body. Here in the tissues, some fluid oozes out of the capillaries and fills the intercellular spaces. This colourless fluid thus accumulated in the intercellular spaces is called **tissue fluid**.

The escape of tissue fluid from the capillaries occurs through small gaps present in the walls of the capillaries. The number of gaps in the capillary walls varies greatly in different tissues of the body. These gaps are quite big so as to allow the passage of fairly large molecules but are not large enough to allow the escape of erythrocytes.

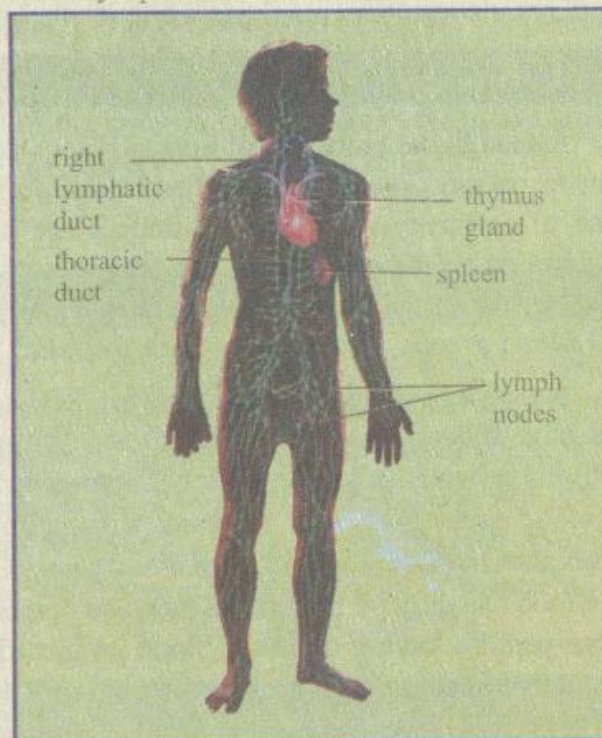
The tissue fluid is the medium through which the exchange of materials occurs, by diffusion, between the cells and the blood in the capillaries.

The tissue fluid also maintains a constant aquatic environment around the cells of the body.

## **12.8 Lymphatic System**

Some tissue fluid present in the intercellular spaces enters the blind lymphatic capillaries (lacteals). After the tissue fluid has entered the lymphatic vessels, it is now called **lymph**.

The excess tissue fluid is returned to the blood through the **lymphatic system**. This system consists of an extensive network of thin-walled vessels, the **lymph capillaries**. The lymphatic system is quite distinct from the blood vascular system. The lymph capillaries have valves in their walls which allow the tissue fluid to enter the lymph capillaries but prevent its flow out of them. These capillaries join together to form larger vessels called the lymph vessels forming the lymphatic system. The lymphatic system serves as an accessory drainage system of the body by removing the excess fluid and dissolved substances that leak from the blood capillaries. The larger lymphatic vessels join the subclavian veins and pour their fluid into them. This is how the lymph is returned to the circulatory system. The lymphatic system transports fats from the intestine to blood stream. It also helps in defending against the attacks of bacteria and viruses by filtering or destroying them at special sites called **lymph nodes**.



**Fig 12.15 The human lymphatic system**



## 12.9 Heart Attack

The heart being a metabolically active organ constantly needs adequate energy and a good continuous supply of blood to carry out its activities. Heart attack can occur due to a number of factors related with the blood circulation and interruption in oxygen supply to heart muscles.

The narrowing and thickening of arteries due to the deposition of cholesterol, fibrin, and cellular debris in the endothelial cells of the arterial wall, and also the accumulation of smooth muscles in the lining of the arteries, can also lead to a heart attack.

If an area of the heart musculature receives insufficient supply of blood, the oxygen supply to this area becomes deficient. Due to deficient supply of oxygen, the cardiac muscles, which are extremely sensitive, will die and this will result in a heart attack. Heart attack may also be caused by a narrowing or clot in coronary blood vessels.

**Angina pectoris** as a mild type of heart attack. It is also caused due to insufficient supply of blood to the cardiac muscles (not to the level that it would cause the death of the heart muscles) due to the narrowing of the coronary blood vessels. The symptoms of angina pectoris are the same as those of the heart attack i.e. chest pain (in the center of chest), and shooting pain in the left arm and the shoulder.

High level of cholesterol in the blood, high blood pressure, increased smoking, increased stress, and increasingly sedentary life style (lack of sufficient physical activity) can also cause heart attacks.

Recovery from a heart attack depends upon the extent of damage to the heart tissue. If the coronary blood vessels of the heart can enhance their capacity to provide sufficient supplies of blood to these tissue, this can bring about recovery from a heart attack.

The interference of blood supply to the brain, which may be due to a blood clot in the blood vessels (carotid vessels) or bursting of blood vessel in the brain, causes brain stroke. Stroke in smaller vessels results in paralysis while stroke in a large vessel may result in death.

## 12.10 Blood Group

Although the blood of all human beings apparently looks alike yet it differs chemically from person to person. The difference lies in the presence of different proteinaceous substances on the surface of erythrocytes. These substances are called **antigens**. These are the naturally occurring substances on the membranes of the erythrocytes. Particular **antibodies** are also found in the blood plasma. On the basis of the antigens and antibodies, the human blood be classified into A, B, AB and O blood groups. This is known as the ABO blood group system.

A person having antigen A on his RBCs would have B-antibody in plasma and so he/she would have blood group A. A person with antigen B on RBCs and A-antibody in plasma would have blood group B; a person with both antigens A & B on RBCs and no antibody in plasma would have blood group AB; and a person with neither A nor B antigens on RBCs and both A- and B-antibodies in plasma would have blood group O. (Table 12.1)

Blood can only be transfused between persons having the same blood groups. If it is transfused between persons having different blood groups, the antibodies present in recipient's plasma destroy the antigen-containing RBCs of the donor. It is called agglutination. Persons with blood group O are called universal donors as they don't have antigens A or B (also don't have antigen Rh). They can donate blood to persons with any blood group. The persons with blood group AB are called universal recipients because they don't have A- and B-antibodies.



**Table 12.1 Human ABO Blood group System**

| Blood Group | Type of antigens on RBCs | Type of antibodies in plasma | Compatible       |               |
|-------------|--------------------------|------------------------------|------------------|---------------|
|             |                          |                              | Can receive from | Can donate to |
| A           | A                        | B                            | A, O             | A, AB         |
| B           | B                        | A                            | B, O             | B, AB         |
| AB          | A, B                     | None                         | A, B, AB, O      | AB            |
| O           | None                     | A, B                         | O                | A, B, AB, O   |

**Table 12.2 Rh factor System**

| Rh Blood type   | Type of antigens on RBCs | Type of antibodies in plasma | Compatible                        |                                   |
|-----------------|--------------------------|------------------------------|-----------------------------------|-----------------------------------|
|                 |                          |                              | Can receive from                  | Can donate to                     |
| Rh <sup>+</sup> | Rh factor                | None                         | Rh <sup>+</sup> , Rh <sup>-</sup> | Rh <sup>+</sup>                   |
| Rh <sup>-</sup> | None                     | Rh-antibody (on stimulation) | Rh <sup>-</sup>                   | Rh <sup>-</sup> , Rh <sup>+</sup> |

In addition to the classical ABO blood group system, there is another set of blood groups, the Rh system. The Rh system consists of Rh-positive (Rh<sup>+</sup>) and Rh-negative (Rh<sup>-</sup>) groups. These groups are identified on the basis of the presence of an antigen called **Rh factor**. If in a person Rh factor is present, he is Rh-positive and if not, he is Rh-negative. These two blood groups are also incompatible i.e. in blood transfusion an Rh-negative person should not be given Rh-positive. On the basis of the Rh factor, the blood groups A, B, AB and O would be A<sup>-</sup> or A<sup>+</sup>, B<sup>-</sup> or B<sup>+</sup>, AB<sup>-</sup> or AB<sup>+</sup>, O<sup>-</sup> or O<sup>+</sup>.

It is always advisable that before giving blood to a person, the blood group compatibility of the donor and the recipients must be checked. The donor and the recipient must have matching blood groups.

### 12.11 Haemophilia

Haemophilia is a hereditary disease in which the patient lacks some blood clotting factors. This disease is characterized by the failure of blood to coagulate. If the persons suffering from this disease have an injury from which blood flows, the blood will not coagulate or clot or will coagulate insufficiently to stop the flow of blood. This may result in excessive loss of blood which in some extreme cases, may prove to be fatal. In a normal human being if an injury occurs which bleed, the blood will soon coagulate and will form a clot at the point of rupture of the blood vessels blocking the blood flow.

### 12.12 Anaemia

Anaemia can be defined as the deficiency of red blood cells in the body. It normally occurs due to rapid loss of blood from the body or below normal production of red blood cells.



## Symptoms of Anaemia

The usual symptoms of anaemia are yellowing of palate, weakness, dizziness, appearance of dark circles around the eyes, thinning of blood, loss of appetite etc.

## Cause of Anaemia

Anaemia can be caused by a number of factors. The main causes of anaemia are:

- (a) Iron is a major component of haemoglobin of red blood cells and an appropriate amount of iron should be available for synthesis of haemoglobin. The deficiency of iron would lead to less production of haemoglobin and consequently less production of red blood cells. As the number of red blood cells will fall down below normal level, the result would be anaemia. This is the major cause of anaemia worldwide.
- (b) Nutritional Deficiency: Deficiency of some important nutrients like vitamin B 12 and folic acid also result in anemia.

## KEY POINTS

1. Water is of extreme importance to living organisms. It plays an important role in the sustenance of life as major component of cell, as a solvent and as a metabolite.
2. Diffusion, active transport and osmosis are the processes involved in the transport of the material across the cells of living organisms as well as between the environmental and organisms.
3. Transpiration is a process of evaporation of water from the aerial parts (cells) of the plant, through structure, like stomata and cuticle. Temperature, wind, humidity, light and atmospheric pressure etc. are the factors which affect the rate of transpiration.
4. From the leaves, synthesized organic materials are transported to other parts of plant such as roots, stems and flowers.
5. Animals may have open and closed circulatory systems.
6. Blood circulatory system consists of blood, heart, arteries, veins and capillaries.
7. Fishes have single-circuit while all other vertebrates have double-circuit circulation.
8. Human heart consists of two atria and two ventricles.
9. Blood consists of plasma, red blood cells, white blood cells and platelets.
10. Human blood group are classified on the basis of A, B and Rh antigens.
11. In haemophilia, blood fails to clot while anemia is the deficiency of red blood cells.

## QUESTIONS

### 1. Fill in the Blanks

- (i) The principal physiological requirement of all organisms is the maintenance of \_\_\_\_\_.
- (ii) The type of diffusion against the concentration gradient (up hill movement) involving the expenditure of energy is called **A** \_\_\_\_\_.
- (iii) The contents of the vacuole of plant cell is called \_\_\_\_\_.
- (iv) The internal pressure exerted on the cell wall by the water moving into the cell is called \_\_\_\_\_.



- (v) A concentration gradient is establishment between the root hairs and the soil water because of the \_\_\_\_\_.
- (vi) Pull or suction force produced in the xylem vessels, because of the transpiration of water from the leaves is called \_\_\_\_\_.
- (vii) The hypothesis proposed to explain the mechanisms of translocation of substances through sieve is the \_\_\_\_\_.
- (viii) Whole blood minus blood cells is called \_\_\_\_\_.
- (ix) Plasma minus fibrinogen is called \_\_\_\_\_.
- (x) The pigment in blood for the transport of oxygen is \_\_\_\_\_.
- (xi) The average number of leukocytes in man is \_\_\_\_\_.
- (xii) The circulatory system in arthropods is \_\_\_\_\_ system.
- (xiii) The artery which supplies blood to the heart muscles, is called \_\_\_\_\_.
- (xiv) The atrio-ventricular apertures are guarded by \_\_\_\_\_.
- (xv) In the normal young adults, the normal blood pressure is \_\_\_\_\_.
- (xvi) The tissue fluid after it has entered the lymphatic vessels is called \_\_\_\_\_.

**2. Write whether the statement is "true" or "false" and correct the statement if it is false.**

- (i) Temperature is an important factor in controlling the rate of transpiration as it influences the opening and closing of stomata.
- (ii) Substances, when dissolved in water, becomes chemically inert.

- (iii) Atmospheric pressure plays an important role in the life of plants as it provides the forces or tension to pull water and minerals ions up the xylem vessels.
- (iv) When guard cells are flaccid, then inner margins curve apart from each other opening the aperture guarded by them.
- (v) The transport of synthesized or stored food, from the leaves or the other storage organs to all other parts of the plant is called translocation.
- (vi) Lymph flows from bigger lymph vessels to the smaller lymph capillaries
- (vii) The inter atrial and inter ventricular septa prevent the mixing of deoxygenated and oxygenated blood, in human heart.
- (viii) In a human the normal blood pressure is expressed as 180/120 mm Hg.
- (ix) Due to over supply of oxygen, the cardiac muscles, which are extremely sensitive, will die resulting in heart attack.
- (x) The persons with blood group O are considered to be universal recipients as they have both antigen A and B.

**3. Each question is followed by four options. Encircle the correct answer.**

- (i) The complexity of transport system is related to:
  - (a) size and the metabolic rate of an organism
  - (b) the type of food taken by an organism
  - (c) to the habitat of the organism
  - (d) all of the above
- (ii) The transport system facilitates:
  - (a) the elimination of metabolic wastes of each cell
  - (b) to adjust in the habitat
  - (c) movement of materials
  - (d) all of the above
- (iii) The diffusion of molecules of some substances with the help of carrier Proteins is called:
  - (a) active transport
  - (b) osmosis



- (c) facilitated diffusion  
(d) cyclosis
- (iv) Chemically the carrier substances in facilitated diffusion are:  
(a) proteins (b) lipids  
(c) carbohydrates  
(d) nucleic acids
- (v) The movement of water into the plant cell produces \_\_\_\_\_ in the cell.  
(a) turgor (b) flacid state  
(c) none of the a and b  
(d) both a and b
- (vi) The internal pressure exerted on the cell wall by the water moving into the cell is called  
(a) root pressure (b) water potential  
(c) turgor pressure  
(d) osmotic pressure
- (vii) The loss of water from cells of the leaves makes their cells:  
(a) turgid (b) flacid  
(c) none of the a and b  
(d) shrunked
- (viii) Because of transpiration pull and cohesion or adhesion of water molecules, the water moves in the xylem vessels as  
(a) packages of water  
(b) an unbroken column  
(c) none of the two  
(d) broken column
- (ix) Whole blood minus blood cells is called:  
(a) tissue fluid (b) lymph  
(c) plasma (d) serum
- (x) If fibrinogen is removed from the blood plasma, the fluid left is  
(a) interstitial fluid (b) lymph  
(c) serum (d) tissue fluid
- (xi) The average number of leukocytes in human beings is  
(a) 15000 to 18000/mm<sup>3</sup>  
(b) 2000 to 3000/mm<sup>3</sup>  
(c) 7000 to 8000/mm<sup>3</sup>  
(d) 1500 to 1800/mm<sup>3</sup>
- (xii) The function of platelets is  
(a) to produce antibodies  
(b) to phagocytose the bacteria  
(c) to form platelet plug or clot  
(d) to carry gases
- (xiii) In single circuit circulatory system, the blood from the heart goes to  
(a) all tissue of the body  
(b) the gills  
(c) the skin  
(d) the lungs
- (xiv) The single circuit heart is found in  
(a) amphibians  
(b) reptiles  
(c) fishes  
(d) mammals
- (xv) The right atrio-ventricular aperture is guarded by  
(a) bicuspid value  
(b) semilunar valves  
(c) tricuspid value  
(d) no values
- (xvi) What is true about lymph capillaries?  
(a) these are blind ended tubes  
(b) these are open tubes  
(c) these are formed by division in arteries  
(d) these join and form veins
- 4. Write short answers of the following questions.**
- (i) What is a clot? What is the function of clot?
- (ii) Name the three general types of cells in blood.
- (iii) What are the two major functions of leucocytes?
- (iv) What important role is played by transpiration in plants?
- (v) Define turgor in plant.



(vi) Define mass flow hypothesis.

(vii) Differentiate between open and closed circulatory system.

(viii) How haemophilia is different from anaemia ?

**5. What are blood groups?**

**List the four ABO blood types. Why is type O blood considered a universal donor?**

**6. What is meant by term Rh positive? How does Rh incompatibility effect blood transfusion?**

**7. Describe the major functions performed by blood.**

**8. Discuss the role of transpiration in plants.**

**9. How food is transported in plants?**

**10. Write notes on the followings:**

(i) Blood pressure

(ii) Lymphatic system

(iii) Heart attack

(iv) Anaemia

(v) Role of water in life



# EXCRETION

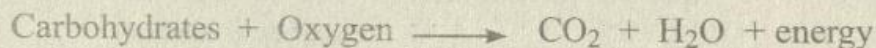
## In this chapter you will learn:

- Definition and need of excretion.
- Waste products in plants.
- Methods of excretion, adopted by plants.
- Types of waste products in animals.
- Excretory organs found in certain animals.
- Excretory system in man, including the structure and function of kidney.
- Brief description of osmoregulatory function of kidney.
- Brief introduction of kidney stone, kidney failure, diagnosis and its treatment.



## 13.1 Introduction

All organisms carry out hundreds of reactions in their bodies which altogether are known as metabolism. The metabolism can be generally divided into two types: the catabolism and the anabolism. The catabolism is the breaking down of complex organic molecules into simpler compounds in order to obtain energy which is utilized for the performance of various activities of life. In catabolic reaction carbohydrates, proteins and lipids are broken down or (oxidized) through enzymatic reactions step by step to generate chemical energy in the form of ATP molecules.



By looking at the above reactions you can know that carbon dioxide, water and ammonia are formed in these reactions. They are regarded as waste and surplus products because they are not utilized in the body of organisms (with the exception of plants which can use  $\text{CO}_2$  for photosynthesis). These waste products must be removed from the body as soon as possible because these are toxic (poisonous) for the cells if they accumulate in the bodies of the organisms. The  $\text{CO}_2$ , if not removed quickly can lead to lowering of pH which can be dangerous for life.

Ammonia is even more toxic than  $\text{CO}_2$ , it should be quickly removed from the body or converted into less toxic material but even then the less toxic materials like urea, uric acid have to be eliminated from the bodies of organisms.

The concentration of water in the tissue fluid of mammals is maintained within the range 97-99% or a mean of 98%. Similarly the amount of water in the blood is regulated at about 92%. If the water exceeds this level then it collects in the tissues causing **dropsy**. If the concentration of  $\text{H}_2\text{O}$  falls below the normal line, it can cause dehydration of body. These waste products which are



actually metabolic by-products have therefore to be eliminated from the bodies of living organisms. The process of removing the waste products from the body is known as **excretion**.

## 13.2 Excretion in Plants

The living organisms differ in their methods of excretion. Generally there are no specialized organs or systems in plants for excretion. The unwanted metabolites may be secreted into intra or inter-cellular spaces. The aerating system of plants makes possible the ready diffusion of respiratory  $\text{CO}_2$  into the surrounding water or atmosphere. In some plants the waste metabolites may be deposited in leaves, seeds and fruits which when shed can easily carry with them these accumulated un-necessary substances. It can be noted that such elimination is purely secondary to the true purposes of leaf fall or seed and fruit dispersal.

### 13.2.1 Removal of Carbon dioxide and Oxygen

$\text{CO}_2$  is produced as a result of **respiration**. As the process of respiration takes place continuously in all living cells,  $\text{CO}_2$  is produced continuously and discharged through the **stomata**, or **lenticels**. On contrary, oxygen ( $\text{O}_2$ ) is released only during the day-time, because it is a by-product of the process of **photosynthesis**. The  $\text{CO}_2$  thus produced during daytime is consumed by the mesophyll cells, in photosynthesis. Only a small quantity of oxygen produced during photosynthesis is used for respiration. The excess oxygen is released from the leaves through stomata.

Green plants give off oxygen as waste in the day time and  $\text{CO}_2$  at night.

At night the photosynthesis stops, the atmospheric  $\text{O}_2$  is used for respiration in plants and  $\text{CO}_2$  is evolved as a by-product.

### 13.2.2 Excretion of Extra Water

Water is one of the major basic needs of the plants. The water in plants is used for photosynthesis, for transpiration and carry out many other functions like transportation of different materials etc. The plants obtain water largely from soil. Whereas a small percentage of it is provided as a result of respiration. The excess water is removed in the form of water vapours by the process of **transpiration**. Sometimes, the removal of this excess water takes place by **guttaion**. For example in cabbage, potato and strawberry etc., the droplets of excess water (similar to the dew drops) often appear at the tips and margins of leaves which enlarge and drop-off later on. In this way such plants and few grasses get rid of the extra water (Fig. 13.1).

**Transpiration:** It is the process by which the water gets evaporated from the plant cells, through stomata etc.



**Fig. 13.1 The phenomenon of Guttation in Strawberry leaves**

### 13.2.3 Latex, Resins and Gums

In some plants the products like latex, resins and gum are secreted in special canals or ducts, present in the plant body. Such products are not ordinarily excreted from the plant, but they trickle out (leak slowly) of the plant when some part of it is damaged. (Due to this unique behaviour, some scientists are also reluctant to regard them as waste products of plants.) The common examples of latex producing plants are Rubber plant and the Pines. **Resins** and **gums** are secreted by *Acacia arabica* (keekar) etc and **mucilage** is secreted by *Hibiscus* (ladyfinger).



### 13.3 Excretion in Animals

The principal metabolic waste products in most animals are water, carbon dioxide, and nitrogenous wastes. Carbon dioxide and some water are eliminated from the bodies mainly by respiratory structures, whereas most of the water and nitrogenous wastes are excreted by special excretory organs.

Nitrogenous wastes includes ammonia, uric acid and urea. Recall that amino acids and nucleic acids contain nitrogen. During the breakdown of amino acids, the nitrogen-containing amino group is removed by a process called deamination and converted to ammonia. However, ammonia is highly toxic. Some aquatic simple animals excrete it in dissolved form into the surrounding water through the process of diffusion before it can build up to toxic levels in their tissues. But in complex terrestrial organisms, including humans, ammonia being very toxic, is converted to some less toxic nitrogenous wastes such as urea or uric acid.

In birds, the frequent excretion of uric acid in the faeces and the absence of urinary bladder keeps the body weight light which is very important for flight.

Uric acid is produced both from ammonia and by the breakdown of nucleotides from nucleic acids. Uric acid is the least toxic and can be excreted in a crystalline form with a little use of water. This is an important adaptation for conserving water in many terrestrial animals such as insects, reptiles and birds.

Urea is the principal nitrogenous waste product of amphibians and mammals. It is produced mainly in the liver. Urea is far less toxic than ammonia and so can accumulate to some extent in the body without causing tissue damage. Because urea is highly soluble, it is excreted dissolved in water. For its excretion, urea needs less water than ammonia but needs more water than uric acid.

#### 13.3.1 Excretion in *Amoeba*

In *Amoeba* and other unicellular freshwater animals contractile vacuoles are present. These contractile vacuoles are osmoregulatory in function as they are involved in the removal of excess water from the body. This water however also carries with it some of the ammonia and  $\text{CO}_2$  which are produced in metabolism. However, most of the ammonia and  $\text{CO}_2$  diffuse out of the body through cell membrane in the dissolved form (Fig 13.2).

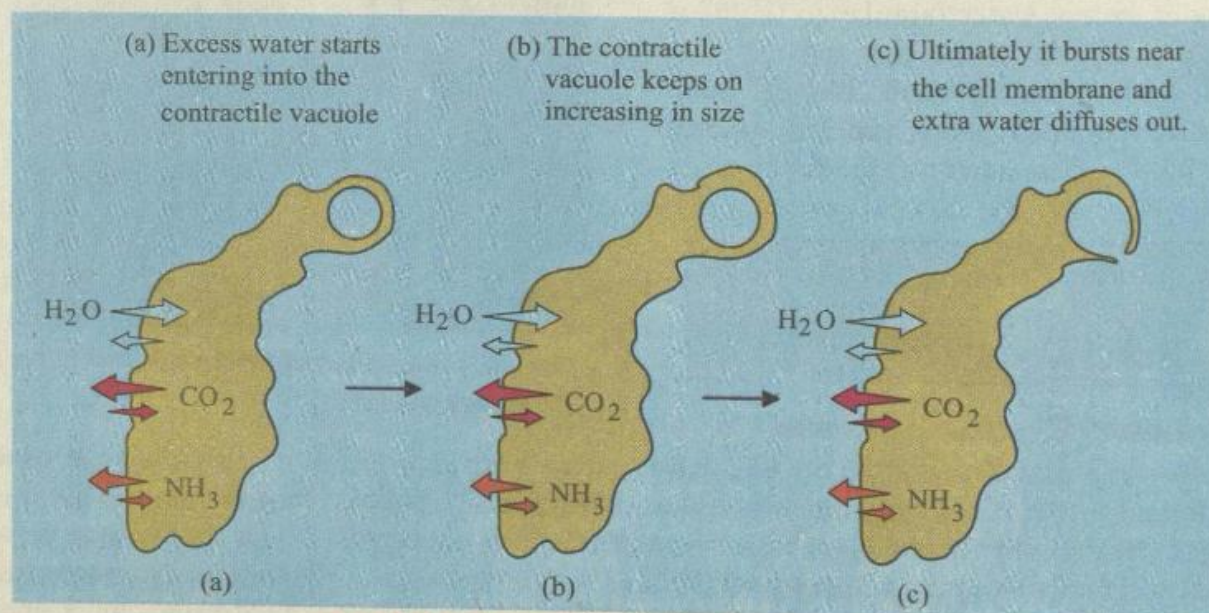


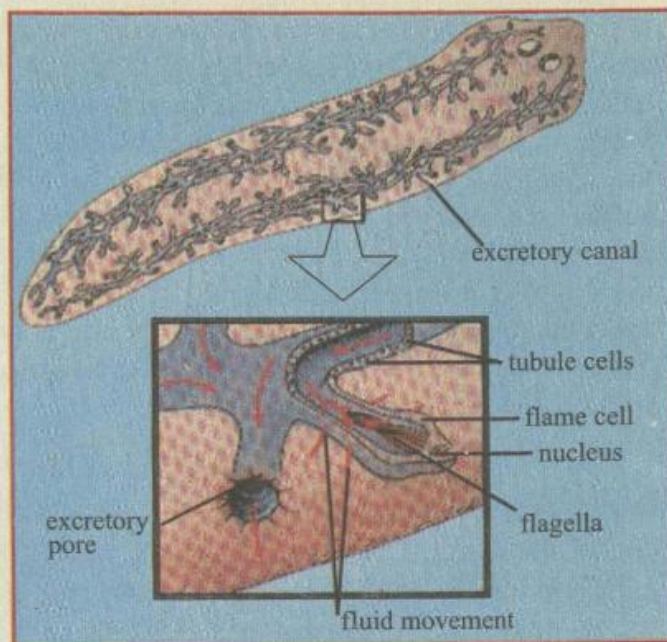
Fig. 13.2 Excretion in *Amoeba*.



### 13.3.2 Excretion in Planaria

In planaria a clearly defined excretory system exists. It consists of two or more highly branched longitudinal tubules. Some side branches of the tubules end in bulb-like cells into which long flagella project. These flagella, beating constantly assume the appearance of a flame and give the system its name – flame cell system. These flagella create continuous currents within the flame cell system and the currents carry

A tuft of flagella present in the flame cell moves in a way similar to that of a flickering candle's flame, thus given the name "**Flame**"

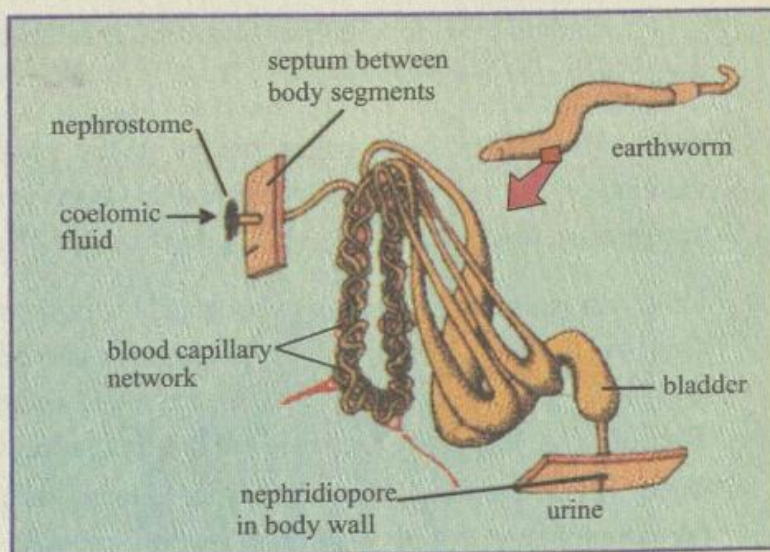


**Fig. 13.3 Excretory system of a Planarian**

fluid and waste materials out of the body through the excretory pores present on the general body surface (Fig 13.3). In planaria, ammonia and extra water are eliminated through this system.  $\text{CO}_2$  is removed through the general body surface by diffusion.

### 13.3.2 Excretion in Earthworm

In the earthworm the excretory system is more advanced and complex than that of planaria. Excretion is carried out by nephridia which are closely associated with its closed circulatory system. Each segment of the earthworm's body contains a pair or in some species a cluster of **nephridia**. The body fluids from the body cavity enter a nephridium through the membrane of a bulb-like nephrostome, which is the ciliated opening into the nephridium.



**Fig 13.4 Nephridium of earthworm**

The nephridium then continues into a coiled tubule which is closely associated with blood capillaries. This allows a selective reabsorption of materials. The nephridium ends into a large bladder, which opens to the exterior by means of a nephridiopore. (Fig. 13.4). Water, urea and  $\text{CO}_2$  are the waste products in earthworm. Most of the  $\text{CO}_2$  diffuses out in dissolved state through general body surface.

### 13.3.4 Excretion in Cockroach

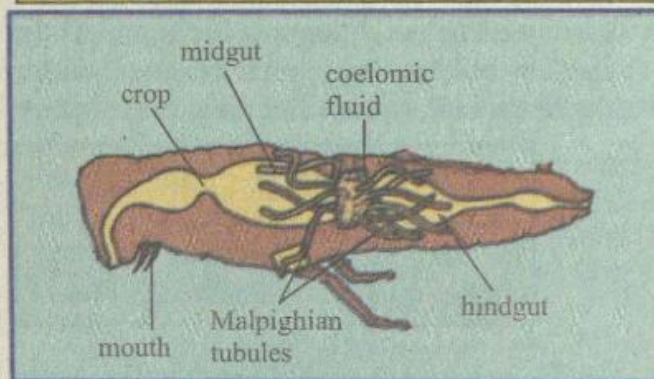
The nitrogenous wastes, inorganic salts and  $\text{CO}_2$  are the major excretory products in insects like cockroach, grasshopper etc. These unwanted and poisonous substances are removed through different organs e.g. **Malpighian tubules** and **tracheal tubules**. The  $\text{CO}_2$  is eliminated from the body



by means of tracheal system. Water, salts and nitrogenous wastes, chiefly in the form of salts of uric acid, are extracted by Malpighian tubules from the haemolymph and pass them in the lumen of the tubules. From here the extracted materials move in the solution form called urine towards the ileum. Water and certain inorganic salts are absorbed from the urine into the proximal part of the tubules. This action of reabsorption leads to the precipitation of the uric acid in the lumen of the tubules. As the urine moves on to the hinder part of the digestive tract, more water is absorbed from the precipitated mass so that solid uric acid is finally thrown out with the faeces.

Malpighian tubules are very fine yellowish thread-like processes which open into the anterior end of the ileum. They are arranged in six groups each having about fifteen blind ended tubules which float freely in the haemolymph. Some uric acid is stored in special cells of the fat body and remain their throughout the life of the cockroach. This is excretion by storage.

The ability to conserve water in the excretory process in insects is highly adaptive and is one of the reasons for these insects for successfully invading dryland.



**Fig 13.5 Excretory system in Cockroach**

### 13.4 Excretion in Vertebrates

Carbon dioxide, mineral salts, urea, creatinin, uric acid, bile pigments and excess water are the waste products in vertebrates.

The kidney is an organ unique to the vertebrates. It is the chief excretory unit in higher vertebrates but its major function in the lower vertebrates (fish) is osmoregulation. In fishes the nitrogenous waste are mainly eliminated through the gills.

In mammals, skin has sweat glands which produce sweat for cooling the body in hot weather. This sweat has some quantities of certain waste products like urea, salts, etc. So skin also acts for excretion to some extent. The lungs as you know are involved in elimination of  $\text{CO}_2$  and water. Some excretion also takes place through intestine as in the amphibians. Main excretory role in reptiles, birds and mammals is however played by a pair of kidneys and their ducts.

In some marine reptiles, external devices have evolved to deal with the excretion of excess salts. These salts excreting glands, are similar to those of birds.

#### 13.4.1 Human Urinary System

The human urinary system consists of a pair of kidneys with attached ureters. The ureters from both sides open into the bladder which opens into the urethra. Each kidney is a bean shaped organ enclosed in a fatty membrane. They are found attached to the dorsal body wall within the abdominal cavity, one on each side of the vertebral column, just above the waist-line. The right kidney lies slightly anterior to the left (Fig. 13.5). The concave side of the kidney faces the vertebral column. The depression in the center of this surface is called hilus. It provides a place for the renal artery, renal vein and nerves to enter and leave the kidney.



The longitudinal section of a human kidney shows that it mainly consists of two regions. The outer dark red region is called **cortex**. The inner pale-red region is called **medulla**. The medulla consists of several cone shaped areas called **pyramids**.

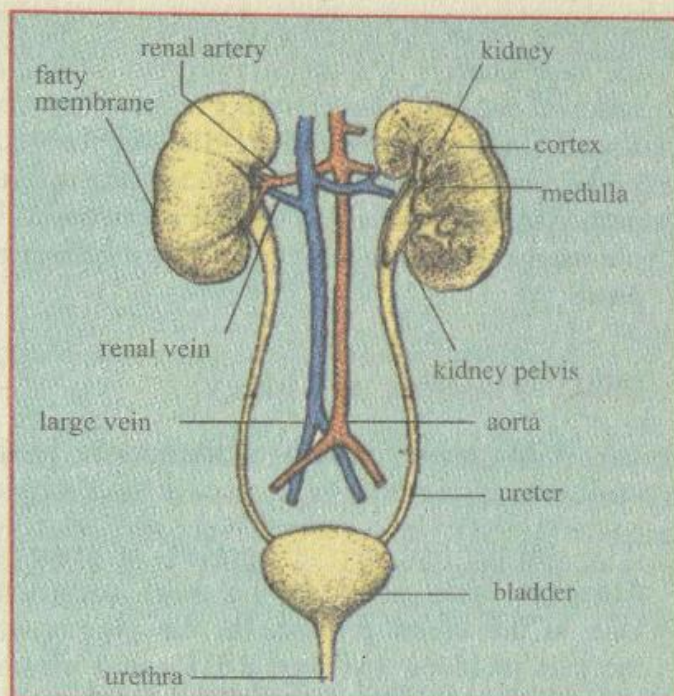
The pyramids project into a funnel-like space present in center of concave surface of kidney called **renal pelvis**.

A tube, called **ureter**, originates from the renal pelvis (of each kidney). The ureters from both the kidneys open in a bladder, called as **urinary bladder**.

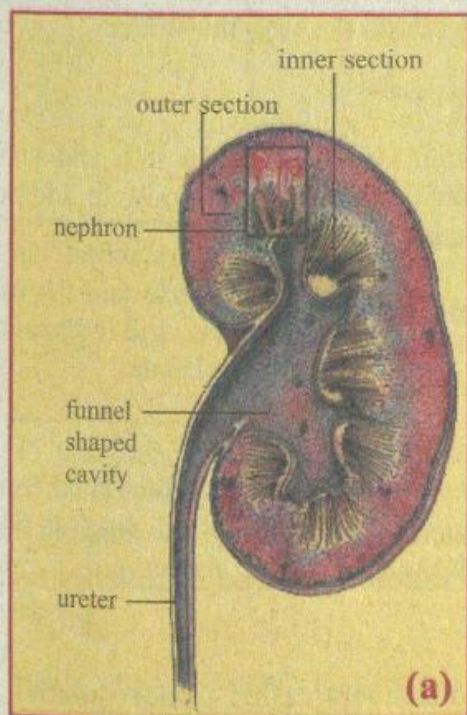
The urinary bladder opens to outside through a duct known as **urethra**.

Each kidney is composed of large number of tiny tubes – the urinary tubules or **nephrons**. Each nephron further consists of a cluster of blood capillaries called **glomerulus** and a long tubule called **renal tubule**. The renal tubule is closed at one end, which enlarges into a cup-shaped structure called **Bowman's capsule**. The Bowman's capsule is surrounding the glomerulus and both are collectively called **renal corpuscle**.  
Fig 13.6 & 13.7.

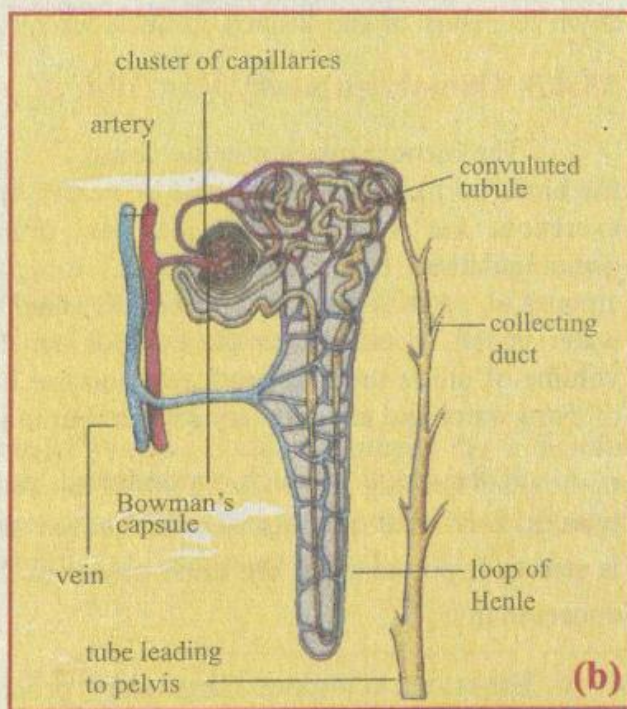
The renal tubule of nephron is much longer and it originates from the Bowman's capsule and its wall is single cell in thickness. It is surrounded by a network of capillaries. Its first portion



**Fig. 13.5 Human urinary system**



**Fig. 13.7 (a) Different regions within human kidney**



**Fig. 13.7 (b) The structure of a single nephron**



is twisted upon itself in a very complex way and the next portion is quite straight but U-shaped called **Loop of Henle** - the name after the scientist who discovered it. The last portion of the tubule is again convoluted and like the last portions of several other nephrons, it ultimately opens into larger duct called **collecting duct**.

### 13.4.2 Function of Kidney:

The main function of the kidney is the urine formation which takes place in three steps:

In the first step, the process of **pressure filtration** takes place in the renal corpuscle. Due to the blood pressure in the glomerulus, the part of blood (without R.B.Cs and plasma proteins) is filtered into the Bowman's capsule and is called **Bowman's filtrate**. It mainly consists of **salts, glucose, urea** and **uric acid** dissolved in water. From glomerulus it trickles down in the **renal tubule**.

In the second step, the process of **selective reabsorption** takes place by the network of blood capillaries which surrounds the tubule. Firstly, all the glucose with much of water is reabsorbed. Then some of the salts are sent back into the blood. In the third step the unnecessary salts together with urea and uric acid (nitrogenous waste products) with excess water (now called **urine**) travel down to pelvis of the kidney, from where it moves to bladder through the ureter.

### 13.4.3 Osmoregulatory Function of Kidney

The osmoregulation is the control of water and other ingredients (like salts and acids etc.) in the blood to maintain a constant or nearly constant water potential in the body. In addition to the excretion, the kidneys also play an important function of osmoregulation. If the blood contains too much water, a small amount of water is reabsorbed from the renal tubules, while more water is left to enter into the bladder. In this manner a large volume of dilute urine is produced, and the human body gets rid of extra water and unnecessary salts and uric acid.

Besides excretion the kidneys help to maintain the pH, blood pressure and composition of blood plasma.

If the blood is much concentrated, more water is absorbed back into the blood from kidney tubules, and small quantity of concentrated urine is produced. The message for drinking more water is sent to hypothalamus, the thirst center in the brain, to restore the blood consistency to its normal concentration.

The above mentioned regulatory processes are collectively called **osmoregulation**, because they regulate the osmotic strength of the blood. The kidneys also regulate the acid-base balance of the body.

#### Practical Work: Examination of a longitudinal section of a mammalian kidney or model of kidney:

- (i) Teacher will make a sheep's / goat's kidney available in laboratory / classroom.
- (ii) Cut it longitudinally into two equal halves. Keenly observe with the help of hand lense and draw the cut surface.
- (iii) Use the similar colours (to the original) in order to differentiate between cortex, medulla, pyramids and renal pelvis.
- (iv) Label the diagram.
- (v) Describe briefly the function of ureter and urinary bladder.



## 13.5 Kidney Failure:

If one kidney of a person is damaged or its nephrons fail to function he can still lead normal life with one fully functional kidney. The question is: What happens if both the kidneys fail to work? The answer is very simple that the person will die, if the proper medical treatment is not given. For this purpose the patient can be treated with a **Kidney machine (dialyser)** and or by a **Kidney transplant**.

### 13.5.1 Kidney Machines (Dialyser)

There are two methods of dialysis, i.e mechanical removal of nitrogenous waste from kidneys.

#### 1. Arterial blood dialysis (haemodialysis)

In haemodialysis an artificial kidney machine called dialyser is used. This machine consists of a tank of sterile dialysis fluid surrounding a long dialysis tubing. Arterial blood from the person with kidney failure is pumped slowly through the dialysis tank via dialysis tubing. The tank contains a dialysis membrane between the blood and the dialysis fluid. Urea and other wastes diffuse from the blood through the dialysis membrane into the dialysis fluid. Blood is withdrawn and send back to the patient by a shunt installed in a fore arm's vein (Fig. 13.8).

Kidney machine is used by the patient twice or thrice a week. This process of removing the wastes from blood takes about four to five hours.

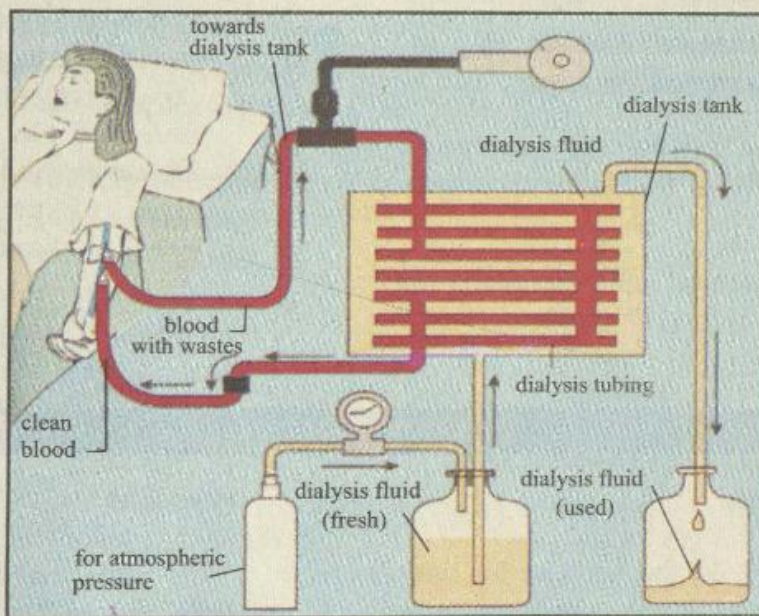


Fig. 13.8 The process of arterial blood dialysis (haemodialysis)

#### 2. Body cavity (peritoneal) dialysis

In peritoneal or body cavity dialysis the sterile dialysis fluid is pumped by a portable machine into the abdominal peritoneal cavity which is the space between the gut and the abdomen. Here the gut capillary walls act as dialysis membranes. Urea and other waste materials diffuse into the dialysis fluid which is drawn by another pump leading the fluid to waste.

### 13.5.2 Kidney Transplant

As the process of dialysis needs to be repeated after every few days and is rather unpleasant, therefore the patient can also be given an alternative treatment that is kidney transplant. In this type of treatment the kidney of a healthy person is transplanted to the patient. The new

In order to get best results in the kidney transplant, the tissue and body chemistry of both the 'donor' and 'patient' must be much similar.



kidney is connected to the patient's blood and urinary system. The kidney may be donated by one of the closest relatives. The tissue and body chemistry of the donor should be similar to that of the patient. When the donor is unrelated or belongs to some other blood group the problems like tissue rejection may occur and the patient's body destroys the donated kidney.

Some other kidney disorders produced as a result of kidney stones or an accidental injury to the kidney may lead to the serious fall in blood pressure.

The kidney stones can be diagnosed by X-rays and sonography by ultrasound machine. The renal surgery for removal of stones is now being replaced in some cases with the lithotripsy (breaking of stone with ultrasound waves).

## KEY POINTS

1. 'Excretion' is the process by which the waste products and excess water is removed from the bodies of both plants and animals.
2. The waste produced in plants are,  $\text{CO}_2$ ,  $\text{H}_2\text{O}$ ,  $\text{O}_2$  and latex etc. whereas that in animals are ammonia, urea, uric acid, extra salts and extra water etc. in addition to water and  $\text{CO}_2$ .
3. The urinary system of mammals mainly consists of two kidneys, ureters and a bladder.
4. The basic structural and functional unit of a human's kidney is 'Nephron.'
5. Besides excretion, the kidney also plays an important role in osmoregulation.
6. "Dialysis" and "kidney transplants" are the two main types of kidney treatment.
7. "Dialysis" is time consuming treatment while 'Kidney Transplant' may fall "tissue rejection", if the new kidney is unrelated to that of the patient. However, both (above mentioned) types of treatment are successfully being used under medical supervision.
8. The kidney disorder like "kidney stone" is also being treated with the "Lithotripsy", these days.

## QUESTIONS

### 1. Fill in the blanks.

- (i) \_\_\_\_\_ is the process by which metabolic waste products and harmful materials are removed from the bodies of living organisms.
- (ii) \_\_\_\_\_ + catabolism  $\longrightarrow$  metabolism.
- (iii) In plants the excess oxygen is removed through \_\_\_\_\_ which lie in the lower epidermis of the leaves.
- (iv) The removal of the waste products from *Amoeba* takes place through the specialized organelles, called \_\_\_\_\_.
- (v) The main excretory organs in planaria are \_\_\_\_\_ and \_\_\_\_\_ attached ducts.
- (vi) The excretory products produced in earthworm are \_\_\_\_\_ and \_\_\_\_\_ in addition to excess water.
- (vii) The excretion in cockroach takes place through \_\_\_\_\_.
- (viii) The major function of kidney in lower vertebrates (fish) is \_\_\_\_\_.
- (ix) The Bowman's capsule surrounds the cluster of capillaries called \_\_\_\_\_.



**2. Write whether the statement is true or false and write the correct statement if it is false.**

- (i) The green plants give off "oxygen" as waste product, during photosynthesis.
- (ii) Respiration is the process by which water evaporates from the aerial parts of a plant.
- (iii) 'Latex' is produced by pines, whereas 'Resins' are the products of 'rubber' plants.
- (iv) In man, the 'left kidney' lies slightly higher than the right kidney.
- (v) Each kidney is composed of a large no. of tiny tubules called, nephridia.

**3. Each question is followed by four options. Encircle the correct answer.**

- (i) The type of activity in which the smaller substances combine to build up the more complex ones is called;
  - (a) Respiration
  - (b) Reproduction
  - (c) Metabolism
  - (d) Anabolism.
- (ii) The excess water in plants is removed by the process of
  - (a) Respiration
  - (b) Transpiration
  - (c) Guttation
  - (d) Both b and c
- (iii) In *Amoeba* ammonia diffuses out through;
  - (a) Mitochondria
  - (b) Golgi complex
  - (c) Nucleus
  - (d) Cell membrane
- (iv) In earthworm the no. of nephridia in each segment is about;
  - (a) Four
  - (b) Five
  - (c) Nine
  - (c) Two
- (v) The part of nephridium which opens into the body cavity by a ciliated funnel is called;
  - (a) Nephridiopore
  - (b) Bowman's Capsule
  - (c) Nephrostome
  - (d) Mouth
- (vi) The name of the common mineral salt present in sweat is;
  - (a) Calcium Oxalate

- (b) Sodium Chloride
- (c) Potassium Sulphate
- (d) Iron Sulphide

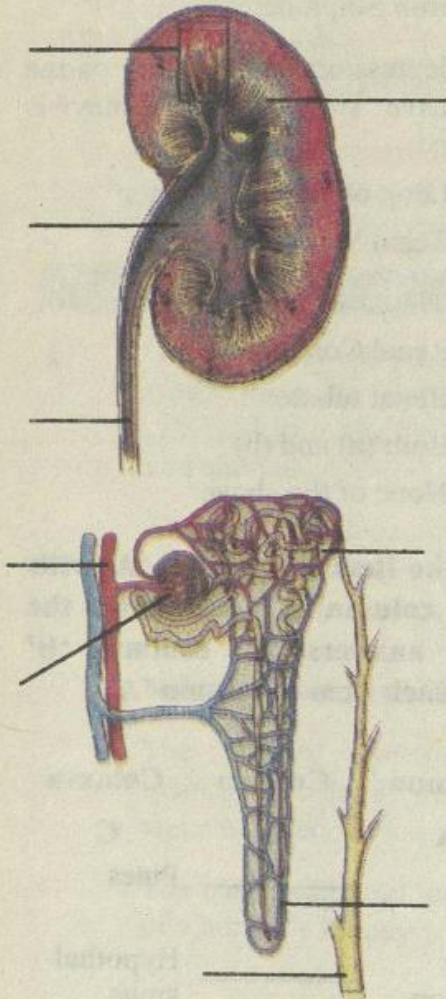
- (vii) The depression in the centre of the concave side of the kidney is called;
  - (a) Loop of Henle
  - (b) Ureter
  - (c) Renal Vein
  - (d) Hilus
- (viii) The 'Nephron' mainly consists of;
  - (a) Renal Corpuscle
  - (b) Renal tubule
  - (c) Both (a) and (b)
  - (d) None of the above

**4. Match the items of column 'A' with that of column 'C' and write the correct answers in column 'B' against each item of column 'A'.**

|        | Column A           | Column B | Column C            |
|--------|--------------------|----------|---------------------|
| (i)    | Latex              | _____    | Pines               |
| (ii)   | Tissue rejection   | _____    | Hypothalamus        |
| (iii)  | Resins             | _____    | Rubber              |
| (iv)   | Thirst centre      | _____    | Planarian           |
| (v)    | <i>Amoeba</i>      | _____    | Human kidney        |
| (vi)   | Earthworm          | _____    | Kidney transplant   |
| (vii)  | Flame cells        | _____    | Nephridia           |
| (viii) | Cortex and medulla | _____    | Contractile vacuole |
|        |                    | _____    | Malpighian tubules  |



5. Identify the following diagrams and label their parts.



6. Write short answers to the following questions:

- What is meant by "Excretion?"
- Briefly describe; Why excretion is necessary?
- Differentiate between 'Catabolism' and 'Anabolism'.
- What is the difference between "Transpiration" and "Guttation."
- Name some waste products produced in plants.

7. Summarize some methods of excretion adopted by plants.

8. What is the main function of kidney? Describe in terms of ultrafiltration, reabsorption and urine formation.

9. Explain the structure of 'Nephron' with the help of a labelled diagram.

10. Write short notes on;

(a) Dialysis (Kidney machine)

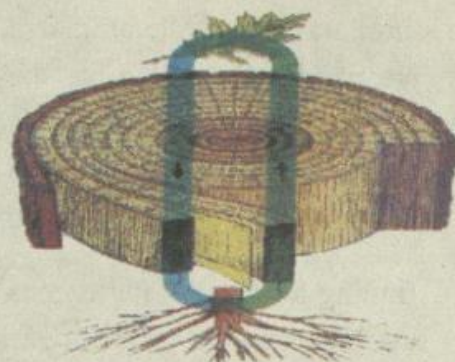
(b) Kidney Transplant.



# SUPPORT AND MOVEMENT

## In this chapter you will learn:

- Importance of support, movement and locomotion.
- Identification, description and microscopic examination of supporting tissues of young and woody Dicotyledonous stem.
- Definition of tactic, nastic, tropic movements; three types of tropism (geotropism, phototropism and hydrotropism) in plants.
- Importance of tropic response and explanation of geotropism in root and phototropism in shoot in terms of auxins.
- Locomotion in plants (*Euglena* and *Volvox*) and in animals (*Amoeba* and *Paramecium*).
- Two types of skeleton (axial and appendicular) and their function in support and movement.
- Role of muscles in the support of skeleton; their movements (action of flexors and extensors) and functions of tendons and ligaments in relation to movements.
- Defects of skeletal system; Joints (ball and socket and hinge) their function and dislocation



## 14.1 Support, Movement and Locomotion

### Support

The need for support became greater as animals and plants increased in size through the process of evolution. This was particularly true for organisms which left the water and colonised land. Support in different organisms may be provided by:

- skeleton as in man and other animals.
- mechanical tissues in woody parts of plants.
- turgidity of parenchymatous tissues in non-woody parts of plant which remain firm and erect because of the pressure within these cells.

During period of water shortage, the tissues of such plants lose water and it results in wilting. Similarly bodies of animals would collapse and fail to maintain shape and posture, if they are not supported properly.

### Movement

Movement is a response shown by a living organism towards or away from the stimulus. It is more clearly visible in most of the animals than in plants. It can occur at:



- **Cellular level** e. g., cytoplasmic streaming and motility of gametes.
- **Organ level**, e. g., heart beat, movement of a limb, shoot, root etc.

**Stimulus** (plural: stimuli) is any influence or change in external and internal environment.  
**Response** is a change in the activity or reaction of the organism to the stimulus.

## Locomotion

Locomotion is the movement of whole organism from one place to another under the influence of a stimulus. Most of the animals have the power of locomotion except a few e.g. corals and sponges. They are fixed to one place but they can move parts of their bodies. Some microscopic water protists e.g. *Euglena*, *Chlamydomonas* are able to move freely from one place to another, they resemble animals in this respect.

Locomotion is used for:

1. finding food by living organisms.
2. avoiding capture by the enemies.
3. dispersal of seeds and fruits
4. finding new and favourable environment.
5. bringing together individuals for reproduction.

## 14.2 Support in Plants

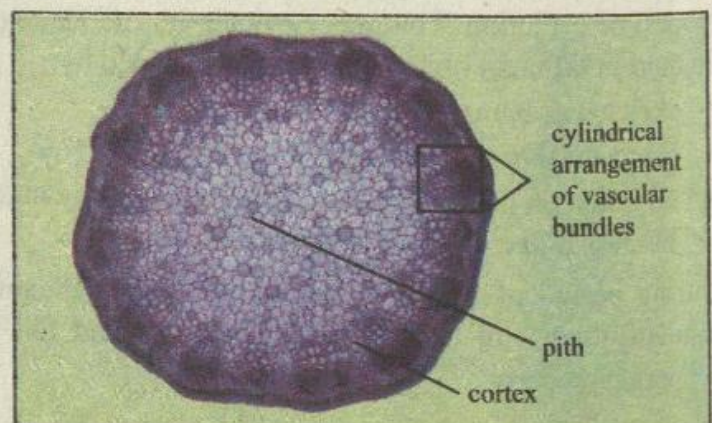
Most plants are stationary. They are not able to move like animals from one place to another. They usually prepare their food themselves during the process of photosynthesis but to fix in one place or position and to keep their whole bodies firm and erect plants should have some supporting tissues and materials. These are present in almost all parts of the body e. g. root, stem, branches, leaves etc. In stem they are in abundance. These supporting tissues keep the stem firm and other parts specially leaves in such a position to get the maximum light for carrying on photosynthesis besides performing other processes.

### 14.2.1 Supporting tissues of young dicotyledonous stem

Young dicotyledonous stem depends for its rigidity or support on the:

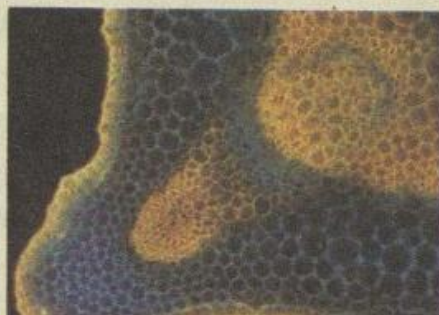
- osmotic pressure and turgidity of parenchymatous tissues,
- the cylindrical distribution of its vascular bundles,
- thick walled collenchymatous (living) and sclerenchymatous (dead) tissues.

In young dicot stem of sunflower (Fig. 14.1), support is due to the cylindrical arrangement of vascular bundles near the outside of stem. Pith is present in the center while cortex is present outside the cylindrical structure. The turgidity and the osmotic properties of the parenchymatous tissues of cortex and those of pith keep the stem stiff and firm. The **parenchyma** (i) becomes tightly packed and appear to serve as packing material; **collenchyma** (ii) in the stem of broad bean provides a flexible support and **sclerenchyma** (iii) thick walled, dead tissues & elongated fibres (iv) often organized in bundles, provide a relatively rigid support to the stem (Fig. 14.2.).



**Fig. 14.1 T. S. of sunflower stem.**





































































































































































































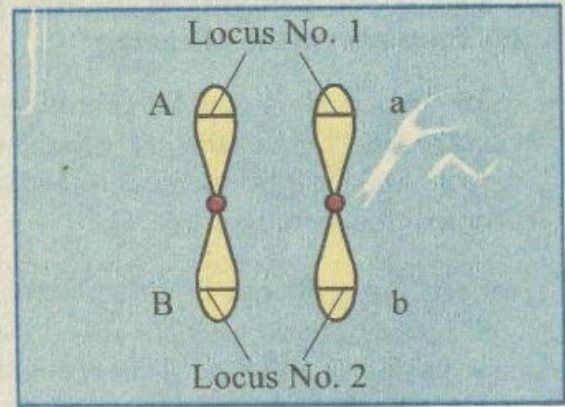


All the genes present on a chromosome are linked to each other. This phenomenon of staying together of all the genes of a chromosome is called **linkage**. Wherever a chromosome moves, it carries its riding genes en bloc in the form of a **linkage group**.

The number of linkage groups corresponds to the number of homologous pairs of chromosomes. You have 23 linkage groups. How many does a frog have?

### 17.2.1 Alleles — Their origin and impact

Like chromosomes, genes also form pairs. Partners of a gene pair are called **alleles**. Each allele of a gene pair occupies the same gene locus on its respective homologue. The partner genes or alleles may be identical to each other; i.e., each other's **true copies**, or slightly different from each other, **altered copies**. These altered, alternative forms of a gene arise by a sudden change in the structure of a gene. This change is called **gene mutation** (Fig 17.1).



|        |                                 |   |
|--------|---------------------------------|---|
| Gene A | $\xrightarrow{\text{mutation}}$ | a |
| Gene B | $\xrightarrow{\text{mutation}}$ | b |

Fig 17.1 Linkage: Allelic pairs on a homologous pair of chromosomes.

## 17.3 Crossing Over and Its Significance

Recall **synapsis** during Prophase I of Meiotic I, when homologous chromosomes pair up lengthwise, point-to-point, and locus to locus. Each homologue consists of two sister chromatids with identical genes. **Chiasmata** or x-shaped cross-links are formed between non-sister chromatids. An exchange of segments between non-sister chromatids of homologous chromosomes occurs at the chiasmata, which is known as **crossing over**. As the alleles of non - sister chromatids are different, crossing over results in **recombination of genes** (Fig 17.2).

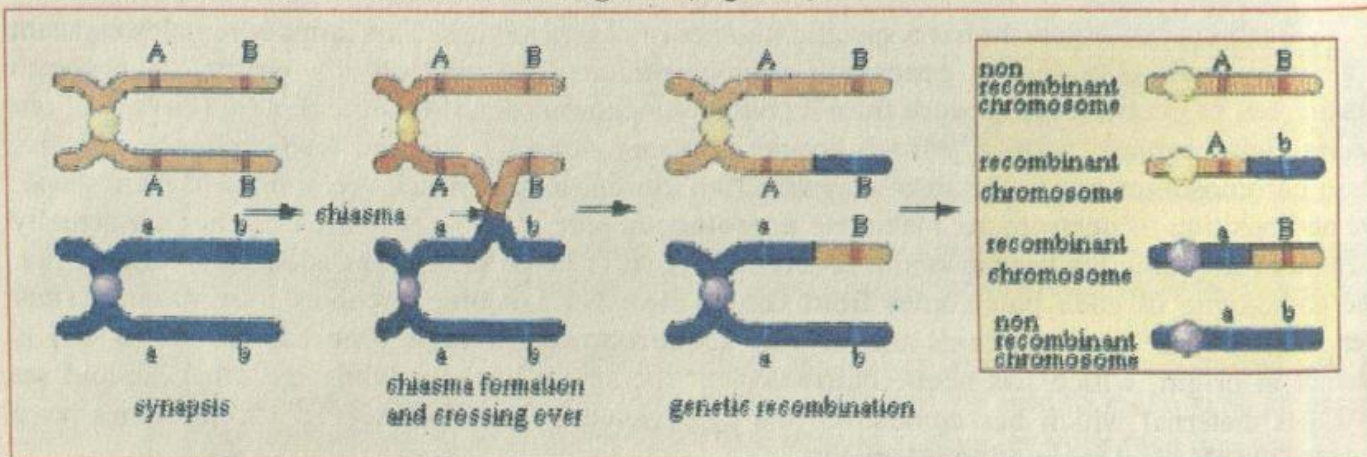


Fig 17.2 Crossing over produces genetic recombination

In the example shown in the figure allele 'b' crosses over to homologue containing 'A' and allele 'B' comes on homologue of 'a'. When the chiasma opens up, the homologous chromosomes separate from each other. The sister chromatids also become

Closer the two gene loci, more strongly are their genes linked. The farther apart two genes lie greater are the chances of their separation through crossing over.



separated to form chromosomes in four gametes. The two gametes would have parental combination of genes; i.e., 'A' with 'B' and 'a' with 'b', whereas two gametes would have chromosomes with new combinations of genes, i.e., 'A' with 'b' and 'a' with 'B'.

### 17.3.1 Significance of crossing over

Gametes with varied combination of genes resulting from crossing over produce genetic variation in offspring. Genetic variations among offspring lead to tremendous variety in their traits. These variations provide raw material for evolution. They may have genetic make up better than their parents to let them adapt to the changing environment in a much better way.

Mutations may give rise to even more than two alternate forms of a gene. Some genes may have as many as 300 alleles. All such alleles (more than two) are called **multiple alleles**. A diploid individual can have any two of these multiple alleles in his genome. In the genome of a haploid organism or in gametes, each gene represents itself as a single allele.

#### Phenotype

Phenotype is the form of appearance of a trait in an individual.

#### Genotype

Genotype is the genetic complement – the genes in an individual for a particular trait.



**Free earlobes**



**Attached earlobes**

**Fig 17.3 Phenotypes of ear lobes.**

Traits may be simple, complex or very complex. Usually a simple trait has at least two distinct phenotypes. e.g.; Ear lobes may hang freely or attach to the cheeks (17.3). Each type of expression is determined by a different allele of the gene. Allele 'A' is determiner

for free earlobes, while allele 'e' is determiner for attached earlobes. More the number of different alleles of a gene controlling a trait, more will be the number of their different forms of expression into different phenotypes. e.g.; Human blood group is a complex trait. It has four phenotypes A, B, AB and O. Three multiple alleles  $I^A$ ,  $I^B$ , and  $i$  take part to make these four phenotypes. Human eye colour is a more complex trait. It has many phenotypes like black, brown, hazel, green, and blue. It needs many gene pairs with their respective alleles to make its many different phenotypes.

Traits with a few phenotypes are determined by a few alleles of a gene. Traits with many phenotypes need many alleles of different genes.



## 17.4 DNA – The Genetic Material

In Prophase, chromatin material condenses into chromosomes. Chemical analysis of chromatin shows that it is composed primarily of Deoxyribonucleic acid (**DNA**) and **proteins**. These are organic molecules.

**DNA is the genetic material.** It is a long molecule about 2 nm thick. It runs continuously within each chromosome. **Genes are short lengths of DNA in chromosomes.** DNA is acidic in nature.

### 17.4.1 Chemical composition of DNA

DNA is a complex macromolecule. **Macromolecules** are very large molecules. It is composed of repeating sub-units called **nucleotides**. Nucleotides are joined together in long chains called **polynucleotides**. The nucleotides of DNA are deoxyribonucleotides. Each deoxyribonucleotide is made up of : (Fig 17.4a)

1. a phosphate group,
2. a deoxyribose sugar, and
3. a nitrogenous base.

There are four different nitrogenous bases: **Adenine (A)**, **Guanine (G)**, **Thymine (T)** and **Cytosine (C)**. Adenine and Guanine are larger double ring bases, called **Purines**. Cytosine and Thymine are smaller single ring bases called **Pyrimidines**. As each nucleotide is named by the base it contains, there are four different types of nucleotides; Adenine nucleotide, Guanine nucleotide, Thymine nucleotide and Cytosine nucleotide (Fig 17.4b). Many of these four types of nucleotides join together to form polynucleotide chain of DNA molecule (Fig 17.4c).

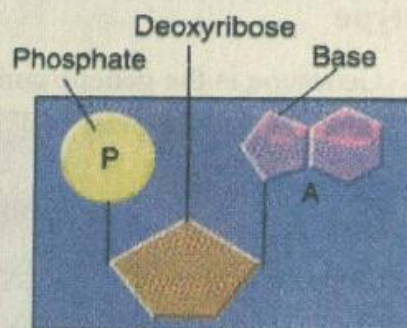
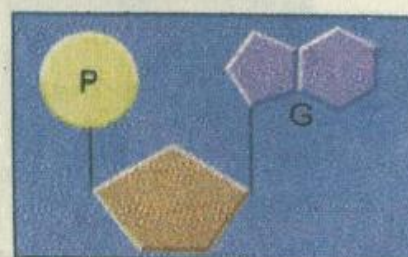
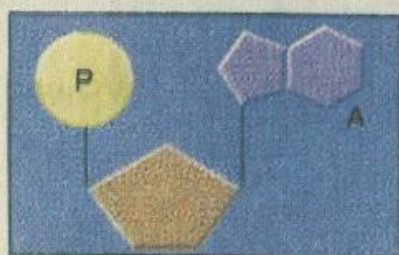
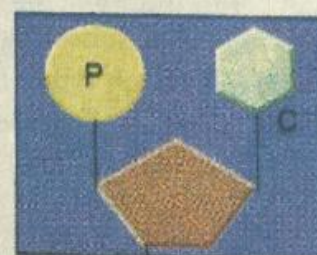


Fig 17. 4(a) A nucleotide



purine nucleotides are larger in size



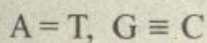
pyrimidine nucleotides are smaller in size

Fig. 17. 4 (b) : Nucleotides of DNA



## 17.4.2 Structure of DNA – Watson and Crick's model

In 1953, James Watson and Francis Crick gave the model for the structure of DNA. They proposed that DNA molecule is made up of two polynucleotide strands, which are twisted around each other in the form of a **double helix**. The double helix looks like a spiral staircase of uniform diameter (Fig. 17.5). The railings of this staircase are composed of deoxyribose sugars and phosphates, while the steps are made of pairs of nitrogenous bases. Each step consists of a purine paired with a pyrimidine. **Their pairing is highly specific.** Adenine always pairs with thymine, and guanine always pairs with cytosine. Two hydrogen bonds are formed between A and T, while three hydrogen bonds are formed between G and C.



Nitrogen base pairing between adenine and cytosine or between guanine and thymine is not possible because such hydrogen bonds cannot be formed. The two polynucleotide strands are held together in their helical configuration by these hydrogen bonds between bases in opposing strands. The base pairs in DNA are 0.34 nm apart, and each turn of the double helix has 10 base pairs. The sugar phosphate backbones of the two complementary strands are anti-parallel ( $\uparrow \downarrow$ ) due to opposite chemical polarity.

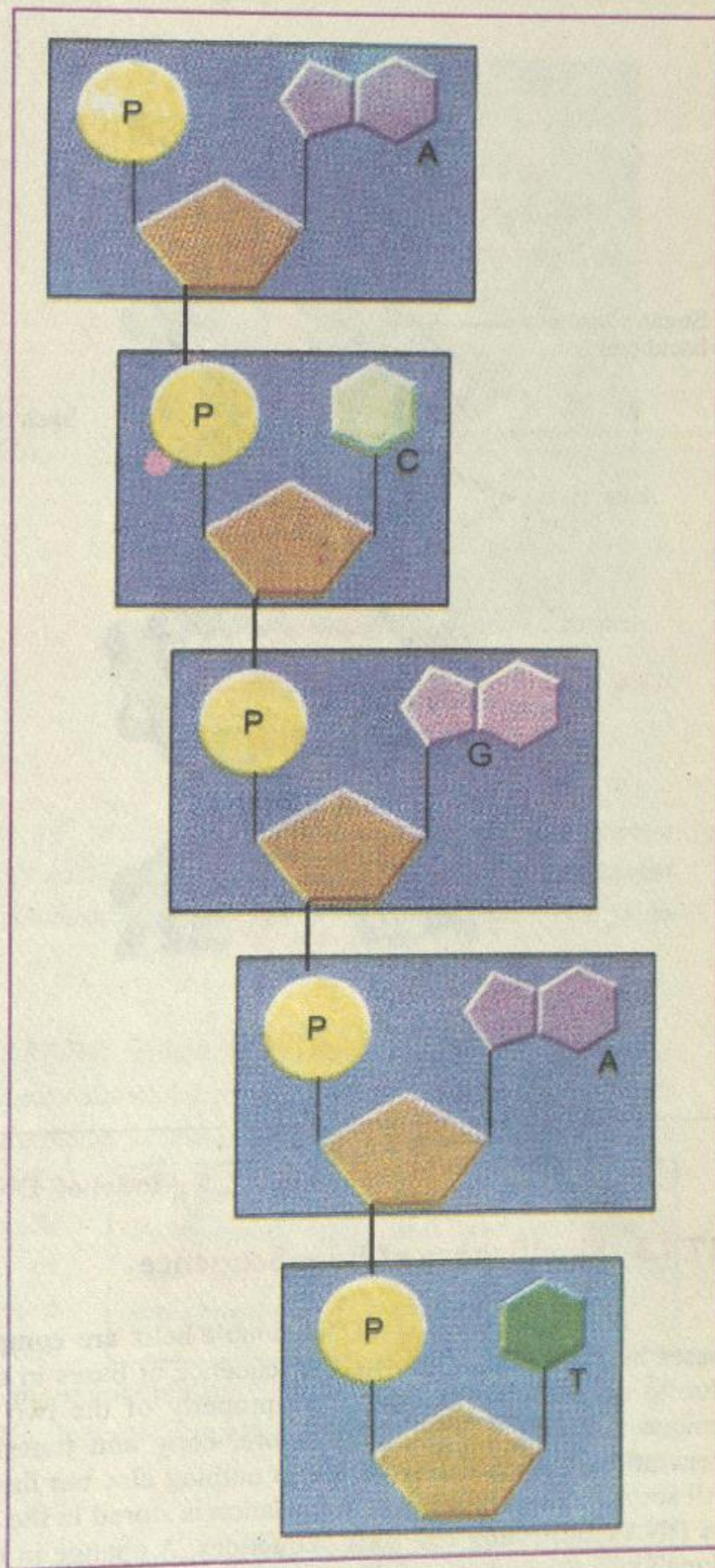
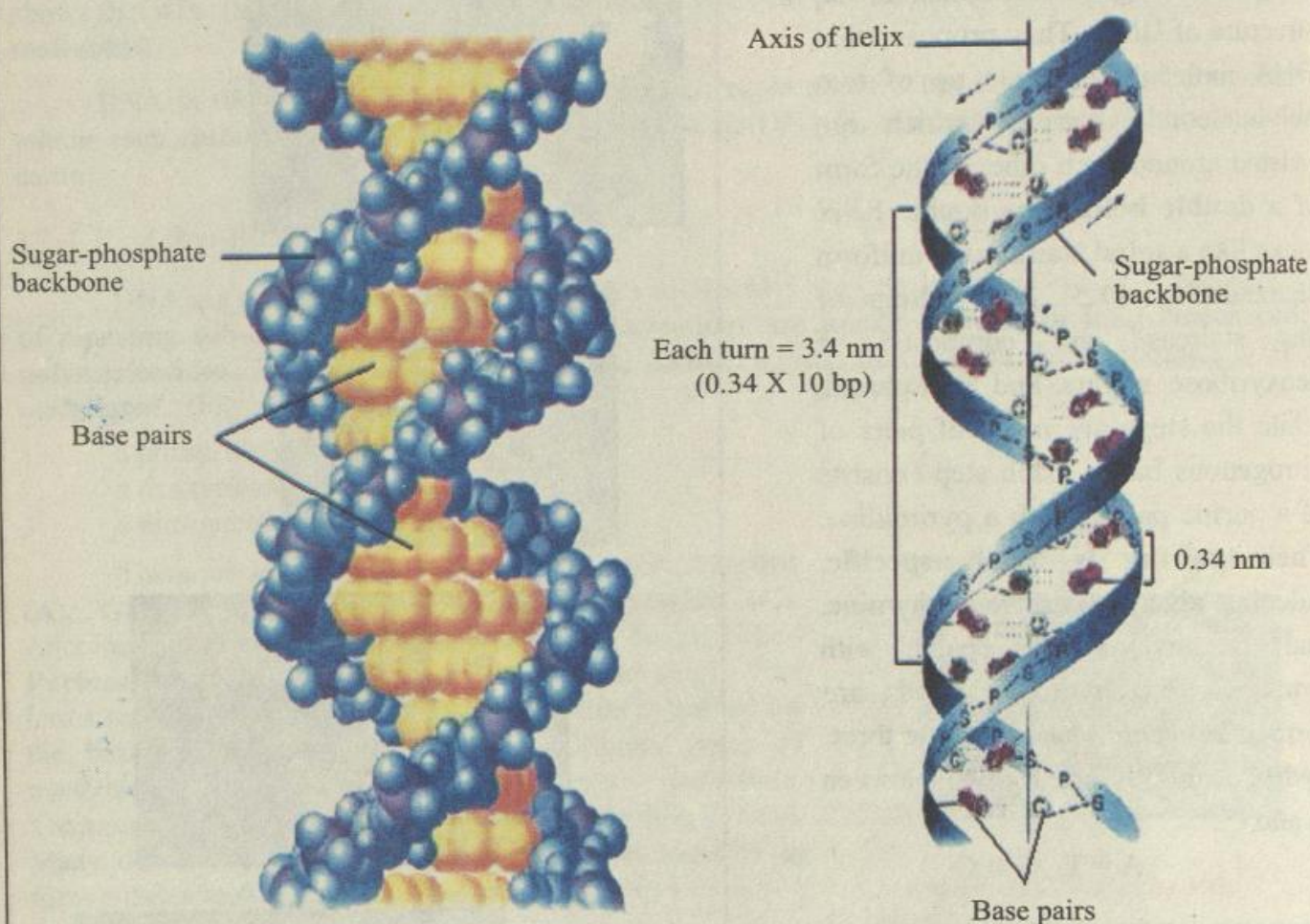


Fig 17.4(c) Polynucleotide chain of DNA





**Fig. 17. 5 Model of DNA molecule**

### 17.4.3 Significance of Base Sequence

The two strands of a DNA double helix are **complementary** to each other. If the sequence of bases in one strand is known, the sequence of bases in the other strand will be automatically known due to specific base-pairing. This property of the two strands of the double helix makes DNA a unique molecule best suited to store, copy and transmit genetic information from generation to generation. **Genetic information** is nothing else but this **base sequence of DNA in a linear order**. All sorts of coded biological information is stored in the form of this base sequence. **Genes are parts of DNA comprising the base sequences**. A change in the base sequence is called **point mutation**, due to which mutated gene becomes different in behaviour from its parental gene.

CTT  $\xrightarrow{\text{Point Mutation}}$  CAT



## Activity No.1: Study of Base Sequence in Structure of DNA

The following is a DNA molecule (Fig 17.6). Carefully look at its base sequence on one strand and construct the complete molecule.

Many base-pair sequences in your DNA are identical to those of your parent's DNA. Despite this striking similarity, much of your DNA is different from theirs due to mutation or genetic recombination. This makes you and your DNA very unique.

DNA stores genetic information in the sequence of its bases in a linear order

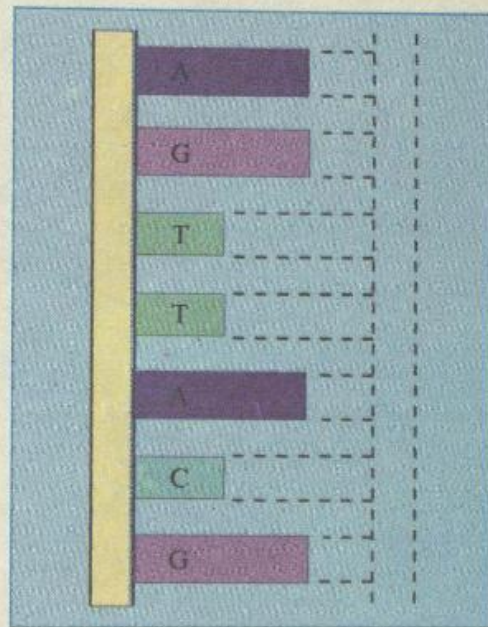


Fig 17.6 Study of base sequence in DNA

### 17.4.4 Replication of DNA

The human genome contains about  $6 \times 10^9$  nucleotide pairs of DNA. All this genetic information must be duplicated immediately before each cell division, so that each daughter cell must have identical information like the parent cell. DNA is the heredity material only because it is capable of self-replication (Fig 17.7).

Watson and Crick proposed mechanism of DNA replication based on complementary base pairing. The DNA molecule begins to unwind at one end. It unzips like a zipper. The hydrogen bonds between base pairs are broken, and the two complementary strands of DNA double helix separate like two halves of an open zipper. A separates from T, and G separates from C. The bases along each parental strand are exposed free. Each strand of the parent DNA now serves as **template**. Its exposed bases can be paired by fresh proper partners. All four types of deoxyribonucleotides are floating in nucleoplasm. Their bases are attracted by complementary bases of each exposed strand. The incoming nucleotides pair their complementary bases on the template.

Each daughter DNA molecule contains one old parental strand and one new strand. That is why this replication is semiconservative – half new, half old.

A complete complementary new strand is formed opposite to each old parental strand. The new strand is exactly like the one that had been separated. Thus two identical double helix molecules are formed from parental DNA molecule.

DNA polymerase enzyme helps in binding the fresh nucleotides to the template strand.



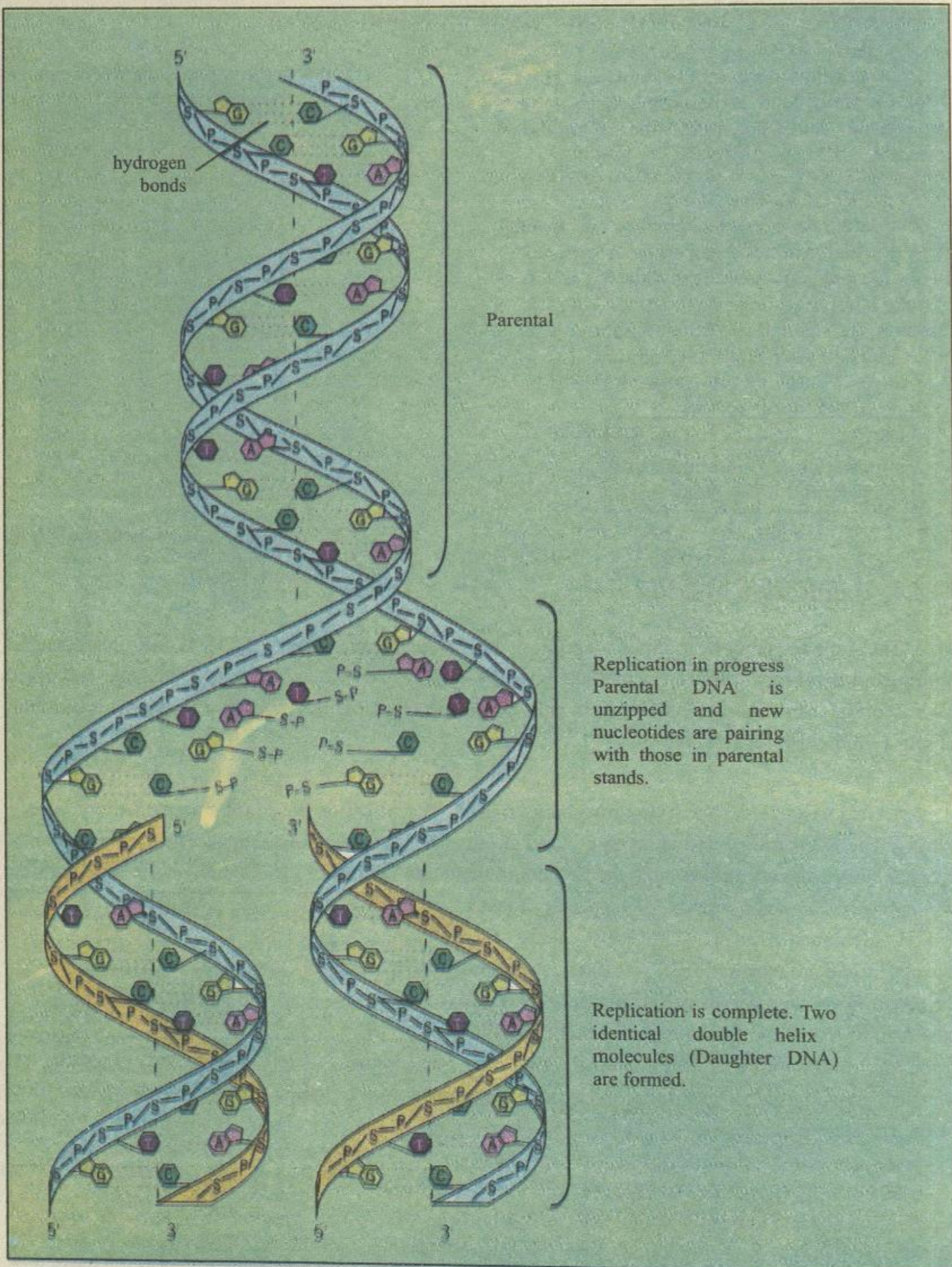


Fig 17.7 Replication of DNA



## 17.5 How do Genes Function ? How is a Phenotype Produced ?

Every phenotype is based on specific biochemical molecules, e.g.; proteins. These proteins are made in the cells under the instructions of genes. Genes sit like a 'Boss' seated comfortably on chromosomes in their office – the nucleus. They get their job done in cytoplasm through their managers – RNAs.

### RNA

RNA is ribonucleic acid (Fig 17.8). It is also a polynucleotide but its basic unit is ribonucleotide. A ribonucleotide consists of a phosphate group, Ribose sugar and a nitrogenous base. Its four bases are adenine (A), guanine (G), cytosine (C) and Uracil (U). DNA controls synthesis of RNA.

RNA is slightly different from DNA:

1. RNA has ribose instead of deoxyribose
2. RNA has uracil instead of thymine
3. RNA is a single polynucleotide strand, but DNA is made up of two polynucleotide strands.
4. RNA is found throughout the cell but DNA is concentrated in the nucleus.
5. RNA is of three types: messenger RNA (mRNA) transfer RNA (tRNA) and ribosomal RNA (rRNA) but DNA has no such types.

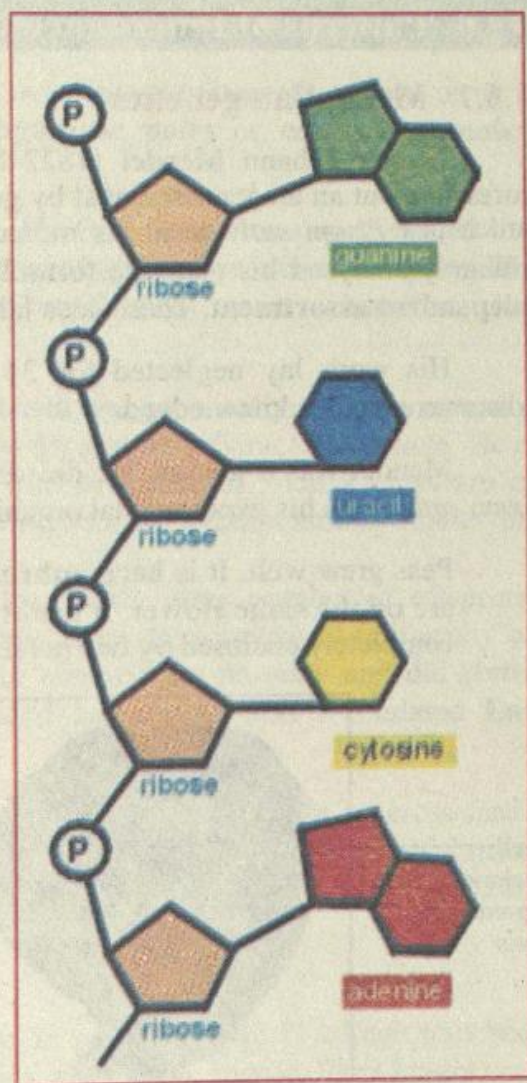


Fig. 17.8 Structure of RNA

A gene expresses itself in two steps (Fig 17.9):

1. **Transcription:** The coded information in DNA, which is there in the form of base sequence, is copied into the base sequence of messenger RNA.

Copying of DNA-encoded information into RNA-encoded information is called transcription. Translation is decoding of mRNA information into a sequence of amino acid in a protein.

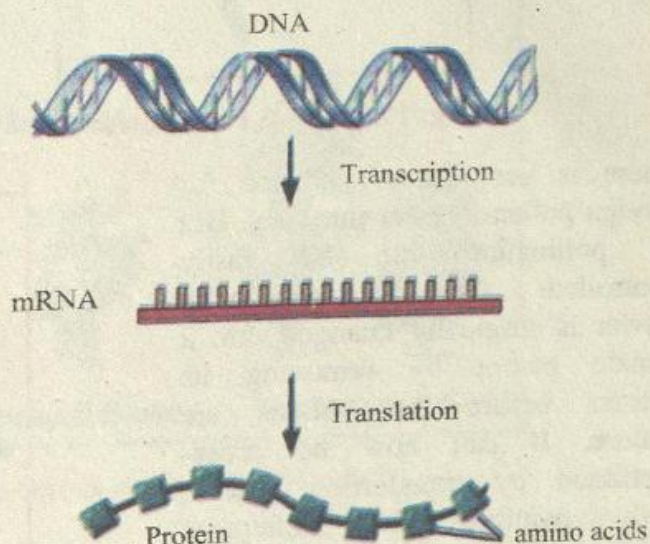


Fig 17.9 Genetic Information flows from DNA to Protein through mRNA



2. **Translation:** The messenger RNA's message is for the protein synthesis. Its base sequence is translated into a sequence of amino acids of a particular protein.

## 17.6 Patterns of Inheritance

### 17.6.1 Mendelian genetics

Gregor Johann Mendel (1822-1884) is called “father of genetics”. He was a priest by profession, but an amateur scientist by genius. In 1854 he began his famous breeding experiments on garden pea *Pisum sativum* in his monastery garden. Mendel performed series of experiments and brilliantly analysed his data. He formulated two laws of heredity; **law of segregation**, and **law of independent assortment**. These laws laid the foundation of **classical genetics** in 1866.

His work lay neglected for 34 years. In 1900, 16 years after his death, his work was rediscovered and acknowledged.

Mendel was a genius. He did differently from other workers of his time. He wisely chose *Pisum sativum* as his experimental organism because he knew its advantages:

1. Peas grew well. It is **hermaphrodite** ( $\text{♂♀}$ ) because both of its male and female sex organs are on the same flower. It is normally **self-fertilizing** because its stamens and carpel are completely enclosed by two petals, which fuse to form a **keel** around them (Fig 17.10 a,b).

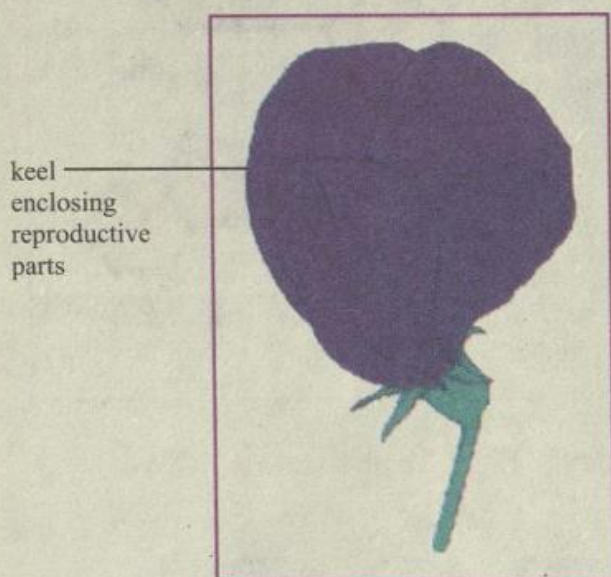


Fig. 17.10(a) A Pea Flower

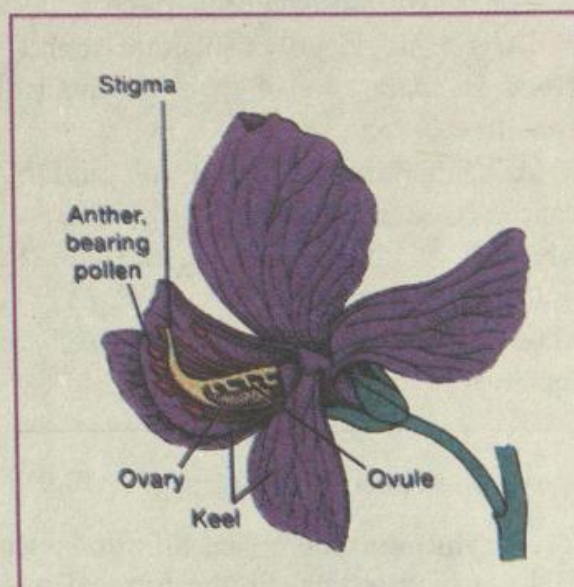


Fig 17.10(b): A pea flower with the keel opened to expose its reproductive parts

There is very remote chance for foreign pollen to enter into keel. But its pollination can be easily controlled. The hermaphrodite flower is surgically changed into a female parent by removing its anthers before the pollens are mature. It can now be **cross-fertilized** by transferring pollens with a paintbrush from anthers of another pea plant taken as the male parent (Fig. 17.10c).

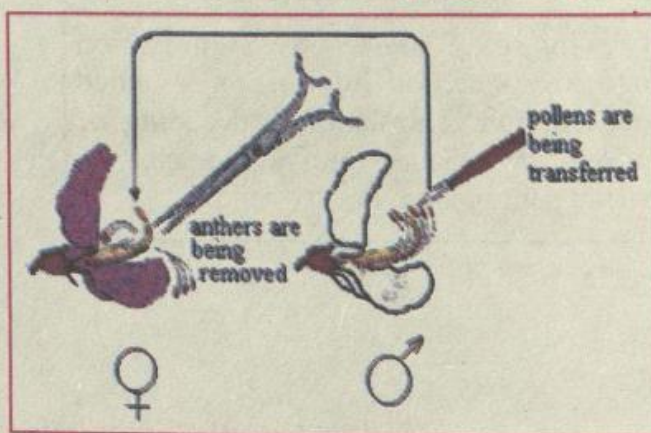


Fig 17.10(c): Cross fertilization of Pea



2. Pea produces a **large number of fertile seeds** within a relatively short growing season. As the time gap between generations is short, many generations can be easily raised within a short time.
3. Pea has many sharply distinct traits. Each trait has two clear-cut alternative forms or varieties. Mendel called such alternative varieties as **antagonistic pairs** or **contrasting pairs**. He settled on seven such pairs for his study.

Mendel's experimental approach was **systematic**. He first isolated and perpetuated lines of pea that **bred true**. Self-fertilization within such **pure-breeding lines** produced offspring like the parents. After establishing 14 true-breeding lines or varieties of seven characters, he did **hybridization** or cross-fertilization.

**Hybrid** is an organism that arises from mating between two genetically different parents.

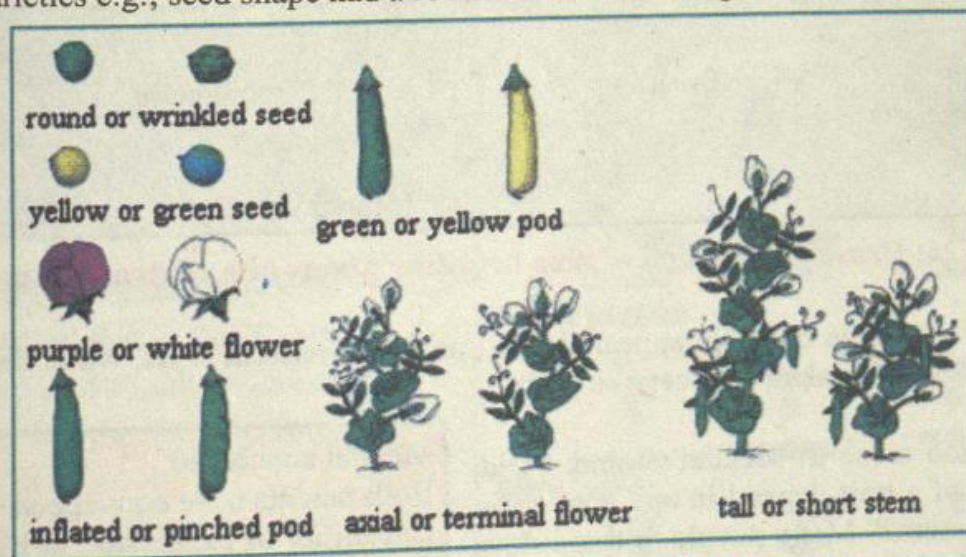
He worked with patience. First he did hybridization for just one character at a time. He cross-fertilized plants differing in one contrasting pair only. The offspring of such a cross are called **monohybrids**. Then he made **monohybrid cross** by allowing self-fertilization among monohybrids.

He worked with large number of plants to produce fairly large number of offspring. He worked on each of the seven pairs of traits separately. His large data increased uniformity of the result and reduced the chance of individual variation. He counted the progeny and did **statistical analysis**. It provided him clear-cut ratios. He compared his results and formulated **Law of segregation**.

Then he studied inheritance of two traits at a time. He made **Dihybrids** by cross-fertilizing plants differing in two contrasting pairs. Then he made **dihybrid cross** by allowing self-fertilization among dihybrids. He counted their progeny and did analysis of his results. He got clear-cut ratio even now. He formulated **Law of independent assortment**.

### 17.6.2 Seven contrasting pairs of traits

Mendel chose to work on seven characters or traits in pea (Figure 17.11). Each trait had two sharply distinct varieties e.g.; seed shape had a round and a wrinkled phenotype. Plant height was

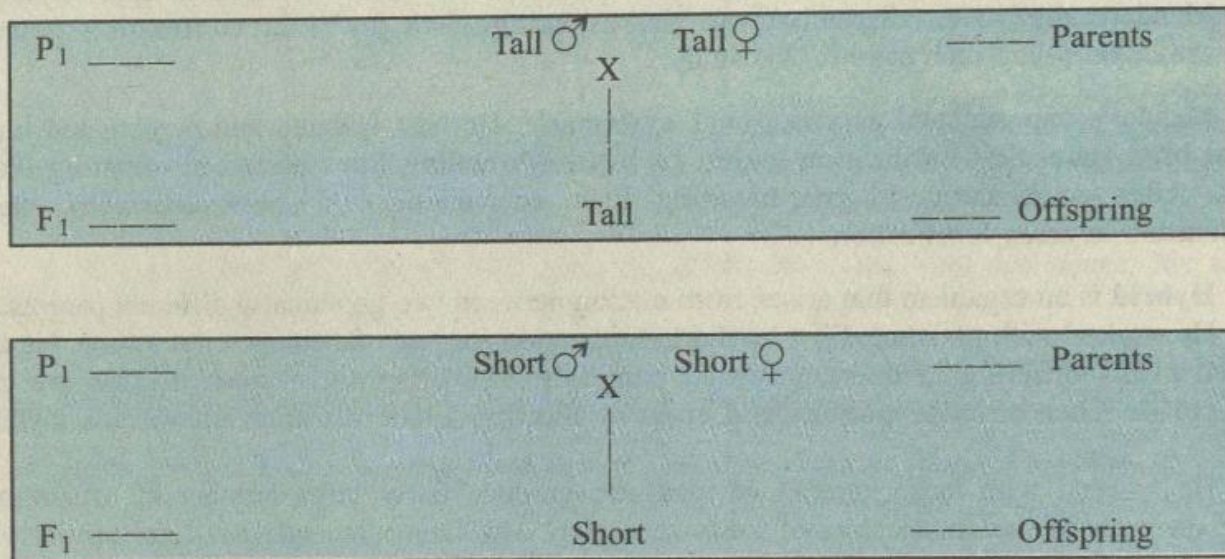


**Fig 17.11: The seven character differences studied by Mendel**

either tall or short. Seed colour could be yellow or green. Mendel called them **contrasting pairs of traits**. Each of this variety bred true generation after generation.



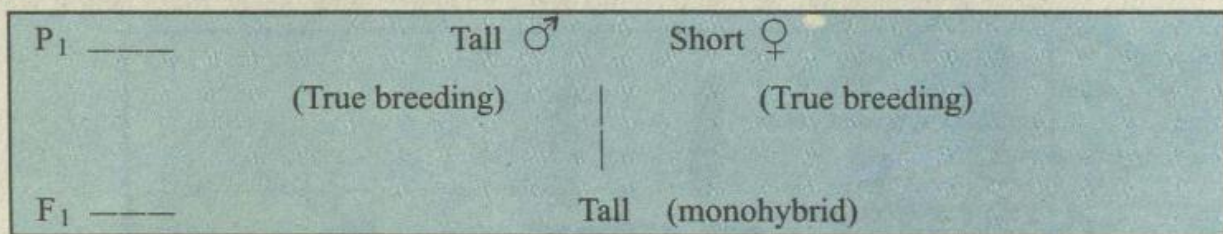
A **true breeding variety** upon self-fertilization always produces offspring identical to the parents. e.g. a true breeding “tall” plant produces only “tall” offspring (Fig 17.12). Similarly a true breeding “short” produces only “short” offspring. He established 14 true breeding varieties of seven traits.



**Fig 17.12: True breeding plants.**

### 17.6.3 Cross-fertilization

Mendel cross-fertilized a true breeding “tall” male plant with a true breeding “short” female (Fig.17.13a). He called this **first parental generation (P<sub>1</sub>)**. Their offspring were called **F<sub>1</sub>** or **first filial generation**. Filial means progeny. All the offspring of F<sub>1</sub> were tall like one of the parents. Short phenotype could not appear. Tall dominated short. Its dominance was complete because no offspring intermediate in size between two parents was found. There was no mixing or blending.



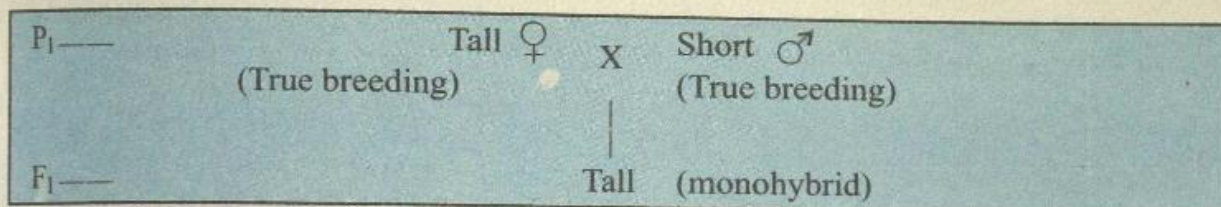
**Fig. 17.13a: Cross fertilization of true breeding plants of a contrasting pair of trait.**

Mendel called the trait that appeared in F<sub>1</sub> as the **dominant trait**; while the trait, which was hidden, suppressed or masked as **recessive trait**.

A question arose in Mendel’s mind. “Did the appearance of a trait depend in any way upon the sex of the parent?” Many people in those days believed in Aristotle’s misconception that only the male parent contributed most to an offspring’s inherited characters. The female parent just served to nourish. In order to test it, Mendel made a **reciprocal cross** by reversing sexes of P<sub>1</sub> (Fig 17.13b).

Mendel concluded:  
Both parents have equal genetic contribution.  
Capability of expression in F<sub>1</sub> is a trait’s own characteristic. It has nothing to do with sex of the contributor.





**Fig 17.13b: Reciprocal cross**

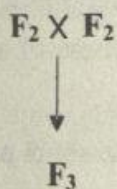
The result was same. Again all F<sub>1</sub> monohybrids were tall. It happened for all the seven contrasting pairs of traits (Fig 17.14).

**Monohybrid cross:** It is a cross between two monohybrids. Mendel self-fertilized F<sub>1</sub> tall plants to raise F<sub>2</sub> progeny. Surprisingly  $\frac{3}{4}$  of F<sub>2</sub> were tall and  $\frac{1}{4}$  short. A clear cut 3:1 ratio was found. The reappearance of short in F<sub>2</sub> indicated that this phenotype though not expressed in F<sub>1</sub>, did exist in some masked form (Fig 17.15). The dominant trait might have temporarily masked its expression, but it could not change or modify its determining nature.

Reappearance of recessive trait in F<sub>2</sub> disproves any blending in F<sub>1</sub>.

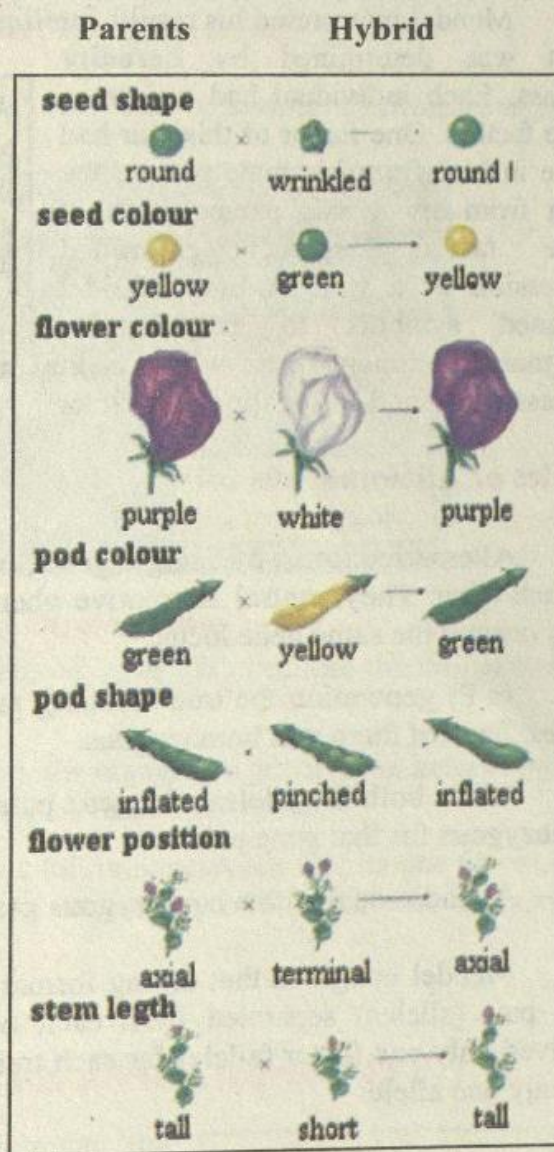
F<sub>1</sub> tall was actually very different from P<sub>1</sub> tall. How? Self-fertilization of P<sub>1</sub> tall produced 100% tall offspring, but self-fertilization of F<sub>1</sub> tall gave 75% tall and 25% short progeny. F<sub>1</sub> tall was not true breeding rather it was a **monohybrid**.

Mendel got the same results and similar 3 : 1 ratio in offspring of monohybrid crosses for all the seven contrasting pairs of traits.



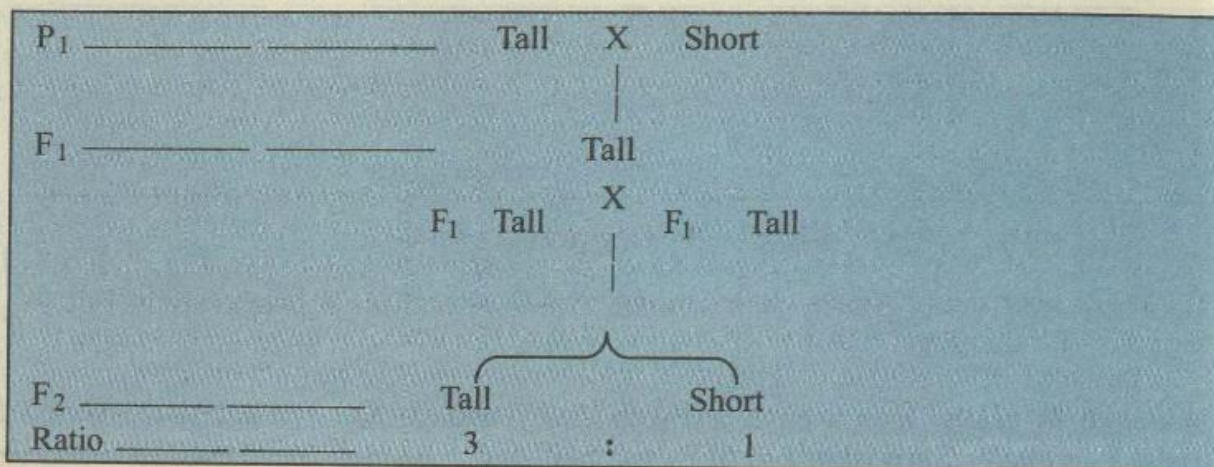
Mendel also raised F<sub>3</sub> generation by self-fertilizing F<sub>2</sub> plants. He found that 1/3 of F<sub>2</sub> tall produced only tall, while 2/3 of F<sub>2</sub> tall produced both tall and short in 3: 1 ratio. But F<sub>2</sub> short produced only short.

Can you say that 1/3 of F<sub>2</sub> tall were like P<sub>1</sub> tall and 2/3 of F<sub>2</sub> tall were like F<sub>1</sub> tall?



**Fig 17.14 Parents with antagonistic traits produced hybrids showing only dominant trait.**





**Fig 17.15: Offspring of monohybrid cross in ratio 3:1**

### 17.6.4 Mendel's Interpretations

Mendel interpreted his results intelligently. He imagined that contrasting form of a trait, tall or short was determined by **heredity factors**. Each individual had a **pair** of these factors. One factor of this pair had come in him from his male parent, the other from his female parent. Both of these factors together controlled expression of a trait in him. Mendel assigned symbols to factors. He designated dominant factor with a capital letter and recessive factor with a small letter, e.g. 'T' for tallness factor and 't' for shortness factor.

What are Mendel's factors? For him these were discrete physical units of inheritance. Johanson coined the term 'gene', and people started calling them genes. Today for us these factors are parts of DNA, the base sequences that carry the biological information to determine a trait. Mendel's factors are alleles of genes.

### Alleles or Allelomorphs

Alternative forms of a single gene are called alleles or allelomorphs. e.g. 'T' and 't' are alleles of each other. They control alternative phenotypes of a trait. They are members of same gene pair. They occupy the same gene locus.

In P<sub>1</sub> generation the true breeding tall plant carried 'TT' alleles while short plant carried 'tt' alleles. Each of them was homozygous.

When both the alleles of a gene pair in an organism are same, the organism's genotype is **homozygous** for that gene pair.

An individual with a homozygous genotype is a **homozygote**.

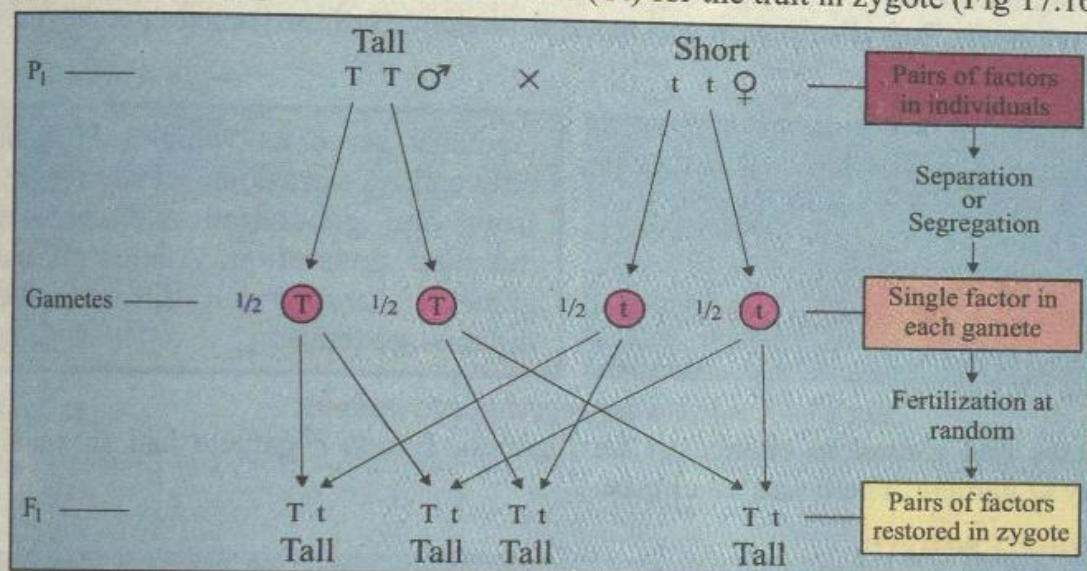
Mendel imagined that during formation of gametes, the factors of a pair (alleles) separated from each other so that each gamete received only one factor (allele) for each trait. Each gamete was "pure" for only one allele.

A homozygote forms all gametes of one type.

Distribution of alleles into gametes was at random. Every gamete had equal chance of getting one allele or the other of a pair. So half the gametes had one allele, and the other half carried the other

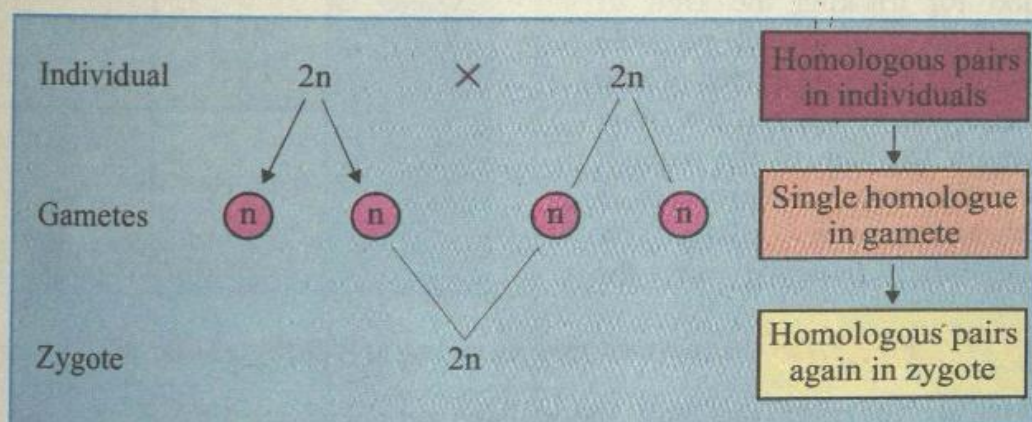


allele. At fertilization male gamete with one factor (T) united at random with female gamete carrying its factor (t) to restore the complete set of two factors (Tt) for the trait in zygote (Fig 17.16a).



**Fig 17.16 (a) : Transmission of Mendelian factors**

Doesn't the mode of transmission of Mendelian factors look like behaviour of chromosomes (Fig 17.16b)?



**Fig 17.16b: Behaviour of chromosomes**

F<sub>1</sub> offspring developing from the zygote was heterozygous 'Tt', because the two alleles of its gene pair were different.

When the alleles of a gene pair are different in an organism, the organism's genotype is **heterozygous** for that gene pair. An individual with a heterozygous genotype is a **heterozygote**.

F<sub>1</sub> offspring was a monohybrid for the trait. It was tall in appearance like its one parent, same phenotype; but actually very different in genetic make up or genotype. Its parent was homozygous tall, it was heterozygous tall.

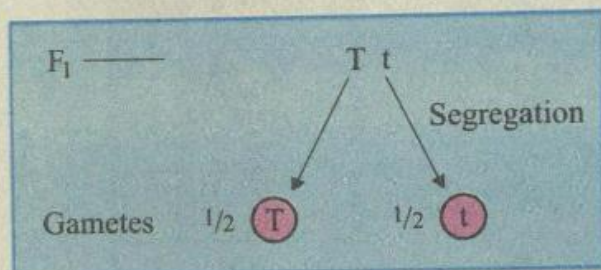
### 17.6.5 How did contrasting factors behave when present together in F<sub>1</sub>?

The two different factors (alleles) in F<sub>1</sub> stayed together and coexisted side by side without interfering or intermingling each other's nature. One (T) became dominant, the other (t) recessive, but their trait determinative natures were not modified.

Dominance only suppresses a recessive gene's expression. It does not affect its nature.



But at the time of gamete formation those two alleles 'T' and 't' separated or **segregated** from each other in a manner that only one allele went into one gamete. Each gamete got only one of the two alleles, not both. Their distribution was again at random. Half the gametes got 'T', the other half got 't' (Fig 17.17).



Gametes serve as vehicles for inheritance between generations. They pick alleles from one generation and carry them to the next generation. Alleles sit quietly in gametes. These do not express till they reach the next generation.

**Fig 17.17: Alleles segregating at random.**

Gametes had a random chance of fertilization. Every ♂ gamete had an equal chance to fertilize every ♀ gamete. There was no choice.

### 17.6.6 Punnett square

Let us visualize self-fertilization of F<sub>1</sub> with the help of Punnett square (Fig 17.18). It is also called checkerboard. Punnett was a British mathematician who introduced it. It is a simple method for tracking the kind of gametes produced as well as all possible combinations at fertilization. Gametes of one parent are arranged on the top, and the other parent's gametes on the side of the square. Each block of the square represents a possible combination of alleles at fertilization, i.e. the genotype of the offspring.

|                |       | Male Gametes |        |
|----------------|-------|--------------|--------|
|                |       | 1/2 T        | 1/2 t  |
| Female Gametes | 1/2 T | 1/4 TT       | 1/4 Tt |
|                | 1/2 t | 1/4 Tt       | 1/4 tt |

**Fig 17.18: Punnett square showing self-fertilization of F<sub>1</sub> to produce F<sub>2</sub>.**

Punnett square indicates that half the pollens produced by F<sub>1</sub> had 'T', and half had 't'. Similarly half the eggs produced by F<sub>1</sub> had 'T', and half the eggs had 't'.

At fertilization 1/4 of F<sub>2</sub> progeny would have been 'TT' (homozygous tall), 1/4 + 1/4 = 1/2 'Tt' (heterozygous tall), and 1/4 'tt' (short).

The diagram illustrates a monohybrid cross between two heterozygous individuals (F<sub>1</sub> generation) with genotype Tt. The gametes produced are T and t. The resulting F<sub>2</sub> generation has four possible genotypes: TT, Tt, Tt, and tt. The phenotypic ratio is 3 Tall (TT and Tt) to 1 Short (tt).

| Generation     | Genotype | Proportion              | Phenotype        |
|----------------|----------|-------------------------|------------------|
| F <sub>1</sub> | Tt       | 100%                    | Tall             |
| F <sub>2</sub> | TT       | 1/4                     | Tall             |
|                | Tt       | 1/4                     |                  |
|                | Tt       | 1/4                     |                  |
|                | tt       | 1/4                     | Short            |
|                |          | <b>Phenotypic Ratio</b> | 3 Tall : 1 Short |

**Fig. 17.19 Monohybrid cross showing genotypic and phenotypic ratios among offspring**



What Mendel really observed in  $F_2$  was phenotypic ratio 3 : 1. By carefully looking at genotypic ratio 1 : 2 : 1 we can easily understand and explain Mendel's data of  $F_2$  (Fig 17.19).

### Mendel's law of segregation

"The two coexisting alleles of an individual for each trait segregate (separate) during gamete formation so that each gamete gets only one of the two alleles. Alleles again unite at random fertilization of gametes."

Mendel's concept of gene, and his law of segregation can be applied to all sexually reproducing organisms.

#### 17.6.7 Test cross

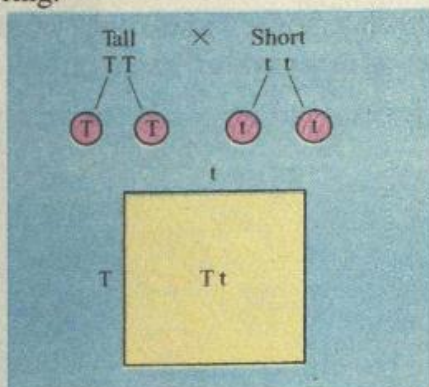
Mendel devised test cross to find out genotype of an individual who had dominant phenotype, e.g. tall.

**Test cross** is a mating in which an individual showing a dominant phenotype is crossed with an individual showing its recessive phenotype (Fig 17.20).

A phenotypically tall individual could be homozygous (TT) or heterozygous (Tt).

##### Case I

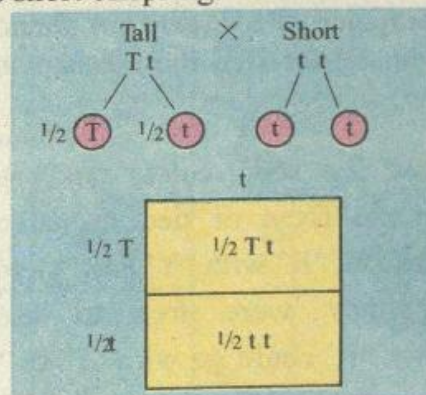
If it is homozygous tall (TT), it will form all gametes with a 'T' allele. Short is always homozygous recessive. It will form all gametes with a 't' allele. Fertilization will result in 100% tall offspring.



**Result:**  
All tall offspring  
The phenotypically dominant individual is homozygous.

##### Case II

If the tall is heterozygous (Tt), it will form half the gametes with a 'T' and half with a 't' allele. Short will form only 't' type of gametes. Fertilization will result into 50% tall and 50% short offspring.



**Result:**  
 $\frac{1}{2}$  Tt = tall,  $\frac{1}{2}$  tt = short offspring  
The phenotypically dominant individual is heterozygous.

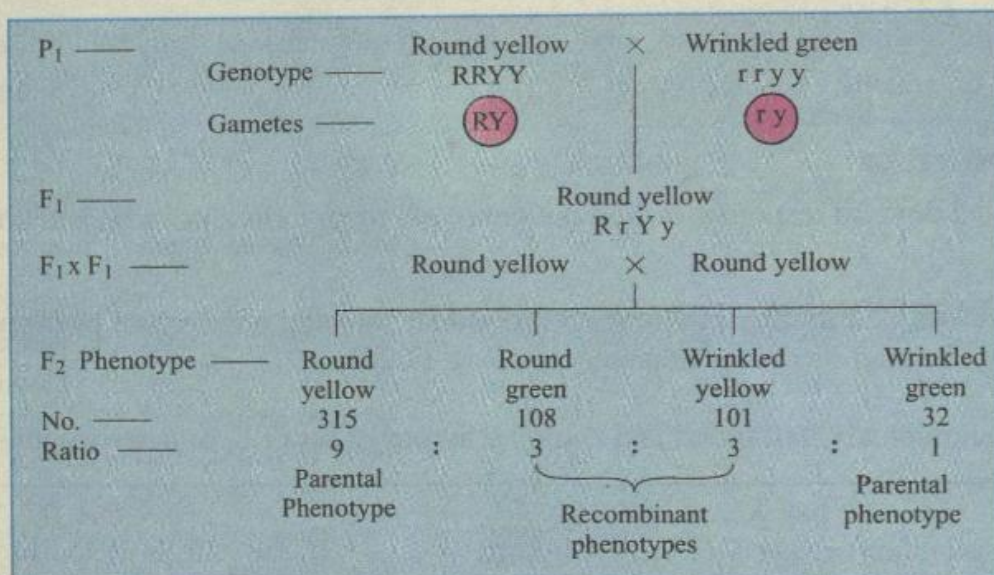
**Fig 17.20: Test cross of a tall plant.**

#### 17.6.8 Inheritance of two traits simultaneously

After thoroughly studying single trait inheritance Mendel decided to go for two traits at a time, e.g. seed shape and seed colour. Seed shape had two distinct phenotypes: seed could be round or wrinkled. Seed colour was another trait. It also had two phenotypes, yellow or green.



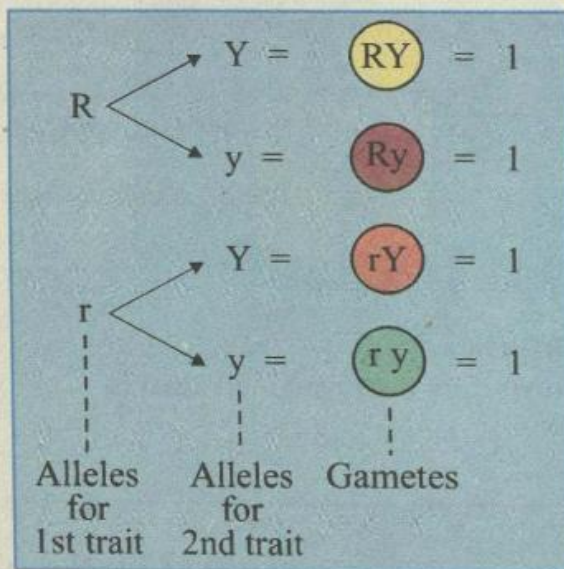
Mendel took true breeding round and yellow seed plants and crossed them to true breeding wrinkled and green seed plants. All the  $F_1$  offspring were round and yellow seeded due to dominance. He allowed these  $F_1$  **dihybrids** to self-fertilize. The result of this **dihybrid cross** was surprising for him.  $F_2$  progeny consisted of not only the two **parental combinations** (round yellow, and wrinkled green) but also two new **phenotypic combinations** (round green and wrinkled yellow). He got 9 : 3 : 3 : 1 ratio among  $F_2$  (Fig 17.21).



**Fig 17.21: Inheritance of two traits simultaneously.**

Appearance of recombinant phenotypes in  $F_2$  indicated that some “shuffling” of alleles had occurred. Mendel inferred the mechanism of this shuffling as **independent assortment of alleles** into gametes.

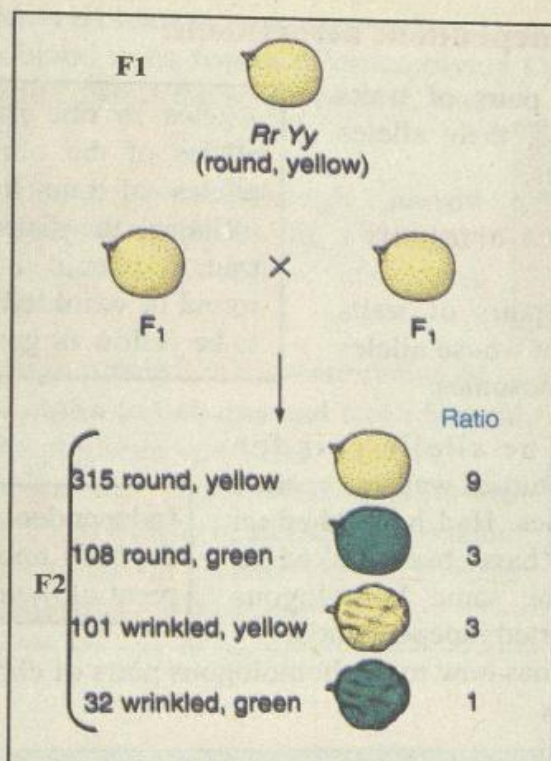
Alleles for seed colour and seed shape were not fixed or tied in parental combinations i.e., ‘R’ with ‘Y’ and ‘r’ with ‘y’; rather they were free to assort independently, ‘R’ could go with ‘Y’ or ‘y’ in any gamete with equal probability. Similarly ‘r’ could go with ‘Y’ or ‘y’ in any gamete with equal chance. Four kinds of gametes were produced in equal number, with a perfect ratio 1 : 1 : 1 : 1 (Fig 17.22).



**Fig 17.22: Independent assortment of alleles into gametes.**

Random fertilization of these gametes would produce 9 : 3 : 3 : 1 ratio (Fig 17.23 a,b)





**Fig 17.23a: The F<sub>2</sub> generation produced from a dihybrid cross.**

|           |                  | ♂ gametes                                                                                                        |                                                                                                                  |                                                                                                                  |                                                                                                                  |
|-----------|------------------|------------------------------------------------------------------------------------------------------------------|------------------------------------------------------------------------------------------------------------------|------------------------------------------------------------------------------------------------------------------|------------------------------------------------------------------------------------------------------------------|
|           |                  | $RY \frac{1}{4}$                                                                                                 | $Ry \frac{1}{4}$                                                                                                 | $rY \frac{1}{4}$                                                                                                 | $ry \frac{1}{4}$                                                                                                 |
| ♀ gametes | $RY \frac{1}{4}$ | $RR YY$<br>$\frac{1}{16}$<br> | $RR Yy$<br>$\frac{1}{16}$<br> | $Rr YY$<br>$\frac{1}{16}$<br> | $Rr Yy$<br>$\frac{1}{16}$<br> |
|           | $Ry \frac{1}{4}$ | $Rr Yy$<br>$\frac{1}{16}$<br> | $RR yy$<br>$\frac{1}{16}$<br> | $Rr Yy$<br>$\frac{1}{16}$<br> | $Rr yy$<br>$\frac{1}{16}$<br> |
|           | $rY \frac{1}{4}$ | $Rr YY$<br>$\frac{1}{16}$<br> | $Rr Yy$<br>$\frac{1}{16}$<br> | $rr YY$<br>$\frac{1}{16}$<br> | $rr Yy$<br>$\frac{1}{16}$<br> |
|           | $ry \frac{1}{4}$ | $Rr Yy$<br>$\frac{1}{16}$<br> | $Rr yy$<br>$\frac{1}{16}$<br> | $rr Yy$<br>$\frac{1}{16}$<br> | $rr yy$<br>$\frac{1}{16}$<br> |

9  : 3  : 3  : 1 

|                                                                                                   |                                                                                                      |
|---------------------------------------------------------------------------------------------------|------------------------------------------------------------------------------------------------------|
|  Round, yellow |  Wrinkled, yellow |
|  Round, green  |  Wrinkled, green  |

**Fig. 17.23b: Punnett square showing genotypic and phenotypic constitution of the F<sub>2</sub> generation**



## 17.6.9 Mendel's law of independent assortment:

“When two contrasting pairs of traits are followed in the same cross, their alleles assort independently into gametes.

### Conditions for independent assortment:

Only those contrasting pairs of traits can show independent assortment whose alleles are riding nonhomologous chromosomes.

Mendel was lucky. The allelic pair for each of the seven characters he studied was on separate homologous pair of chromosomes. Had he studied an eighth trait, its alleles would have been linked to alleles of any other trait on the same homologous pair, and could have never assorted independently.

Can you guess why? Recall pea has how many homologous pairs of chromosomes (Fig 17.24).

Alleles in one pair inherit independently of alleles of the other pair. The distribution of alleles of one trait into gametes does not influence the distribution of alleles of the other trait. It means that chance for a plant to be round or wrinkled is independent of its chance to be yellow or green.

Independent assortment of genes depends upon independent assortment of their chromosomes.

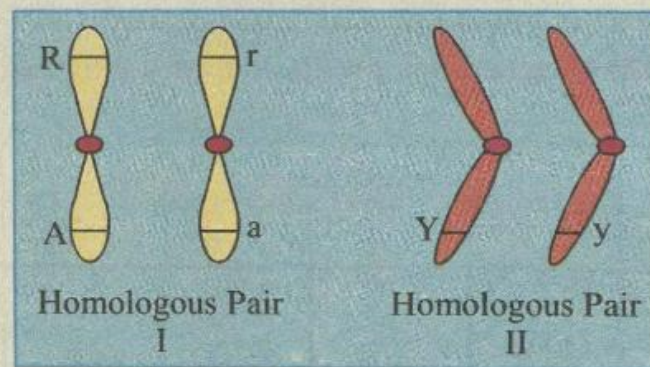


Fig 17.24: What would happen if another gene pair 'Aa' also rides homologous pair I? Can it assort independently of 'Rr'?

## 17.7 Mendel's law and we the humans

Mendel's principles of classical genetics are fundamental laws. These are widely applicable to all organisms. Let us apply his law to human genetics.

### 17.7.1 Sickle-cell anaemia

Sickle-cell anaemia is a **hereditary disease**. The blood of affected individual has a reduced capacity of delivering oxygen to tissues. Haemoglobin is the oxygen-carrying protein in our red blood cells. It gives red blood cells their colour. Red blood cells with normal haemoglobin are in the shape of a biconcave disc. They easily pass through capillaries and supply oxygen to tissues.

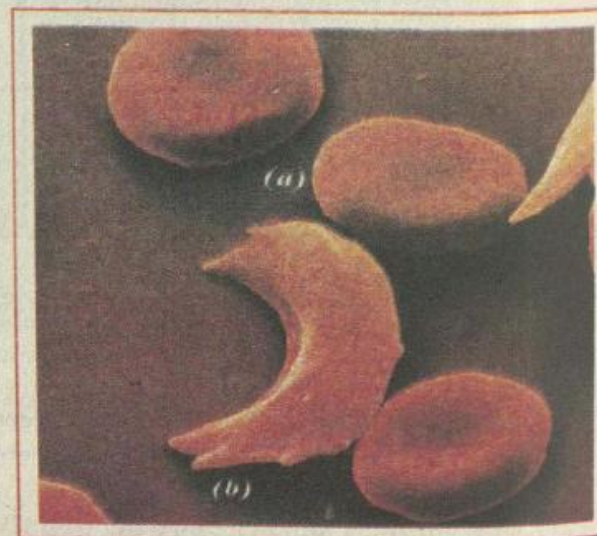


Fig. 17.25: a = Normal RBC, b = Sickle-



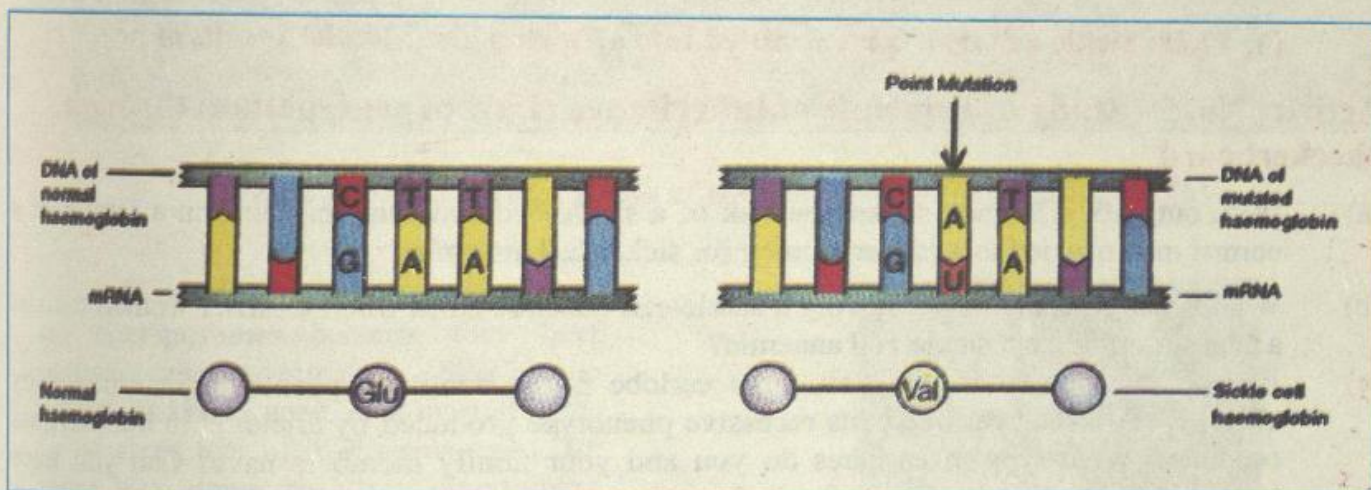
Red blood cells with sickle-cell haemoglobin appear normal so long as oxygen is plentiful. As the oxygen level drops when blood exits tissues after supplying  $O_2$ , this haemoglobin forms insoluble fibrous strands. These strands distort the shape of RBC into long thin sickles (Fig 17.25).

Distorted cells cannot pass through narrow capillaries. So capillaries become clogged. The tissues are starved for oxygen. Sickle-cells may rupture and cause anaemia.

Haemoglobin is a large protein. It has four chains of amino acids; two identical **alpha ( $\alpha$ ) chains** and two identical **beta ( $\beta$ ) chains**. The alpha chains of normal and sickle-cell haemoglobin are alike, but their  $\beta$ -chains differ by a single amino acid. The amino acid **glutamic acid** at 6<sup>th</sup> position is replaced by **valine** in sickle-cell  $\beta$ -chain. The  $\beta$ -chain of normal haemoglobin is encoded by a gene called human  $\beta$ -globin gene (HbA) Fig. (17.26).

A hereditary disease is a body malfunction caused by a gene. It cannot be cured unless the malfunctioning gene is repaired or replaced by a normal one.

Anaemia is a condition of blood with lack of red corpuscles.



**Fig 17.26: The point mutation causes sickle-cell anaemia.**

The DNA triplet of HbA gene encoding for glutamic acid is CTT. A point mutation changes just the middle base of the triplet from T to A. As it becomes CAT a new allele HbS emerges. CAT encodes for valine. So, the allele for normal haemoglobin is HbA and allele for sickle-cell haemoglobin is HbS. These are present on chromosome No:11 (Fig 17.27).

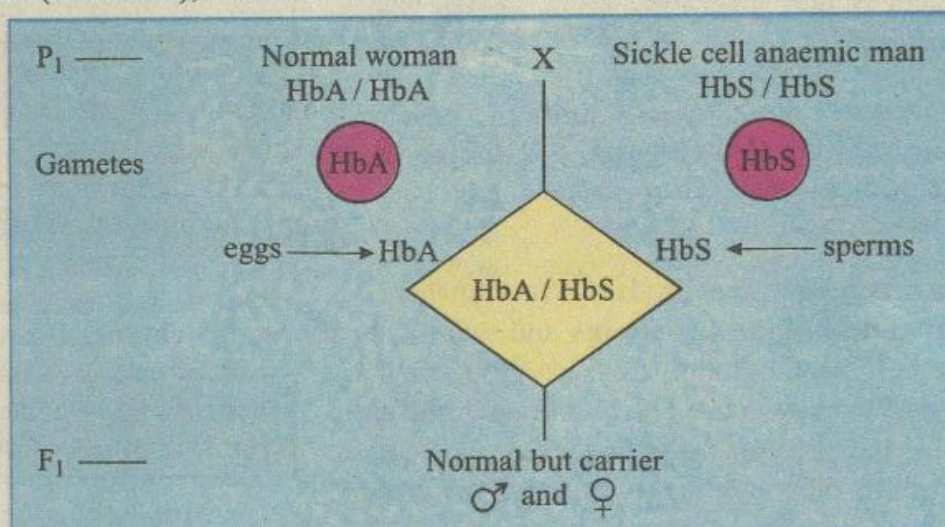
Individuals homozygous for normal haemoglobin are HbA/HbA. They do not have the disease. Homozygotes for sickle-cell allele HbS/HbS have the disease. Heterozygotes HbA/HbS are called **sickle-cell carriers**. The carriers show no symptoms of the disease under normal circumstances. Only 1% of their RBC becomes sickle shaped.



**Fig 17.27: Human chromosome 11 with linked genes of sickle-cell anaemia and albinism.**



It is an autosomal recessive trait (Fig 17.28). If a normal woman (HbA/HbA) marries a sickle-cell anaemic man (HbS/HbS), all their children will be carrier (HbA/HbS).



**Fig 17.28: Sickle-cell trait is transmitted into offspring like Mendel's traits of pea.**

### Activity No. 5: Study of Principle of inheritance (Law of segregation) through checkerboard

- Work out with a Punnett square the risk of a sickle-cell anaemic childbirth in a family of a normal man married to a carrier woman for sickle-cell anaemia.
- What is the probable risk of having a sickle-cell anaemic child when a carrier woman marries a man suffering from sickle-cell anaemia?
- Earlobe is a normal human trait. Free earlobe is the dominant phenotype determined by allele 'E'. Attached earlobe is its recessive phenotype produced by allele 'e' in homozygous condition. What type of earlobes do you and your family members have? Can you trace transmission of this trait in your family?

### 17.7.2 Diabetes Mellitus

It is a **hereditary disease** caused by a recessive allele 'd' in homozygous condition. Diabetics are unable to use glucose in their body metabolism. They pass glucose in their urine. Normal individuals have dominant allele 'D'. Their urine is without glucose.

Can you guess why the chances of diabetes in children increase when both parents are diabetics, than when one parent is normal but the other diabetic?

### Activity No. 6: Study of principle of inheritance (Law of independent assortment) through checkerboard.

If a man suffering from diabetes but homozygous normal for haemoglobin marries a woman homozygous normal for sugar metabolism but suffering from sickle-cell anaemia, what are the chances in their children of being diabetic and sickle-cell anaemic at a time?

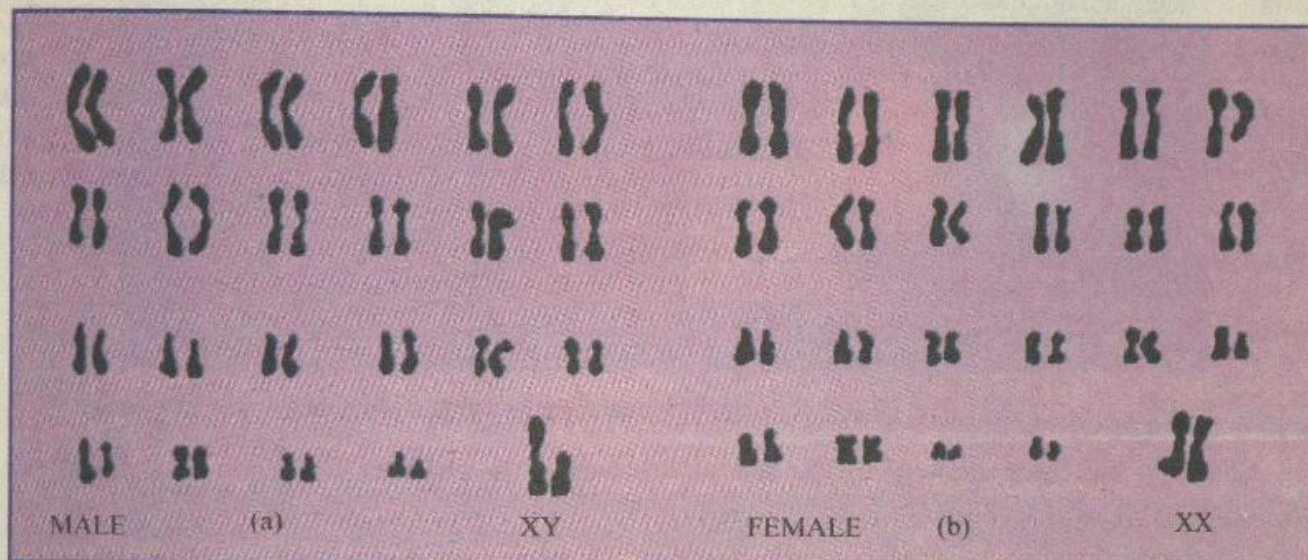
## 17.8 Sex determination in Man

As you have already studied, we humans have 46 chromosomes in the form of 23 homologous pairs (Fig 17.29). When we compare karyotype of a human male with female, we notice that 22 pairs are common in both. These chromosomes are **autosomes**. But the 23<sup>rd</sup> pair is very different in males



and females: A woman has two similar chromosomes in her 23<sup>rd</sup> pair. These are called X-chromosomes. She is XX.

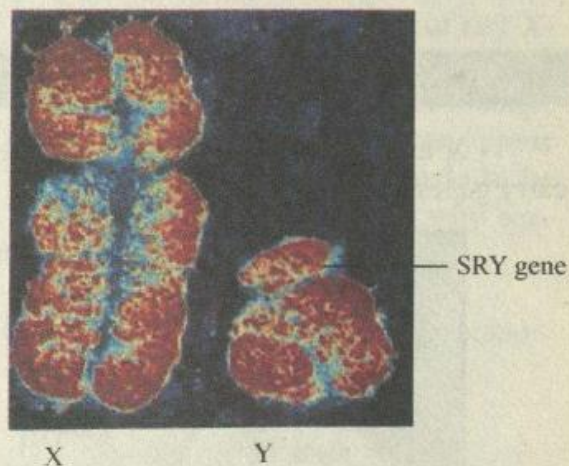
The chromosomes of 23<sup>rd</sup> pair of a man are morphologically different from each other. One is X-chromosome while the other much shorter is Y-chromosome. He is XY.



**Fig: 17.29 The chromosomes of the human male (a) and female (b)**

X and Y chromosomes are called **sex chromosomes** because they have genes for sex determination. 'SRY' is the male determining gene. It is located at the tip of short arm of Y-chromosomes. Its name SRY stands for "sex determining regions of Y" (Fig17.30).

Autosomes do not carry any sex-determining gene. All chromosomes other than sex chromosomes are called autosomes. The genes on autosomes determine autosomal traits.

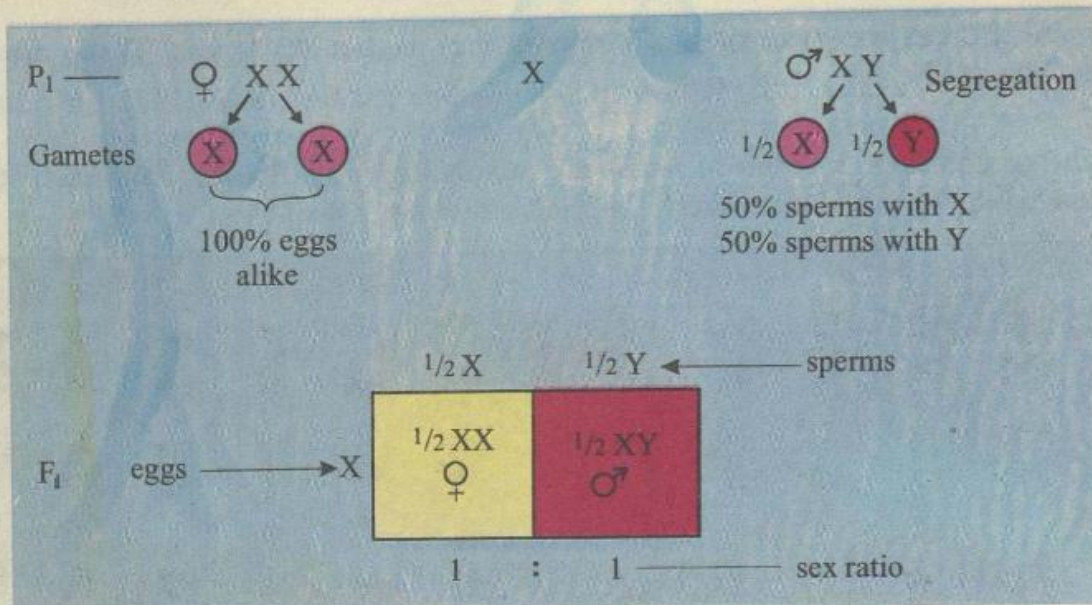


**Fig: 17.30 The X and Y chromosomes of man.**

When chromosomes segregate at meiosis, each homologue of the 23<sup>rd</sup> pair also moves in one gamete. A woman being XX produces eggs, each with an X-chromosome. As all her eggs are alike she is **homogametic**. A man is XY. He produces two types of sperms, half carrying X chromosome, the other half carrying Y. He is **heterogametic**. Chances for both types of sperms are equal.

Sex of the baby is determined by the type of sperm. If an X-carrying sperm fertilizes the egg, the zygote will be XX, and a baby girl is born. If a Y-carrying sperm fertilizes the egg, the zygote will be XY; SRY gene expresses itself and a baby boy will be born (Fig 17.31).





**Fig 17.31: Sex determination in man.**

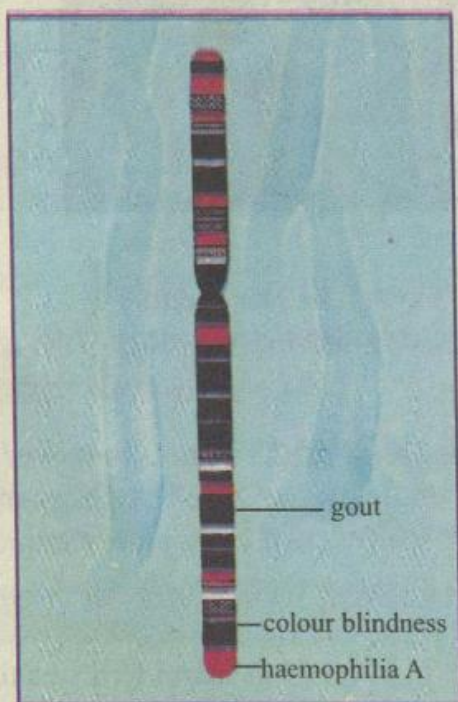
Sex ratio indicates chances of the sex of the baby. Are chances for a son or a daughter not equal?

A son receives his only X-chromosome from his mother and Y from his father. A daughter receives one X from her father and the other X from mother.

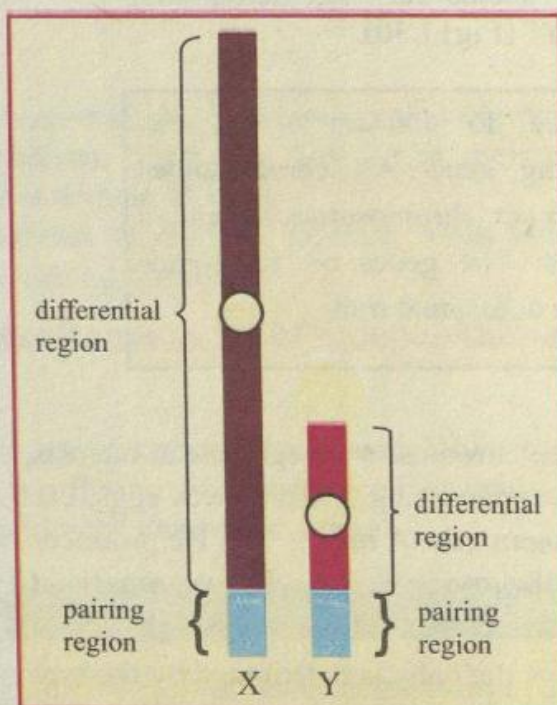
Who is more responsible for determination of sex of a newborn baby, father or mother?

## 17.9 Sex linkage in man

X and Y chromosomes are different in size. In addition to sex-determining genes they also carry genes for many other traits.



**Fig 17.32: The human X chromosome**



**Fig 17.33: Human X and Y-chromosomes.**



Many genes are present only on X-chromosome. These have no corresponding alleles on Y-chromosome. These are **X-linked genes** and their traits are **X-linked traits**; e.g., colour-blindness, and haemophilia. X-linked traits are also commonly called **sex-linked traits** Fig (17.32). A few genes are present only on Y-chromosome, having no counterpart on X-chromosome. These are **Y-linked genes** and their traits are **Y-linked traits**. Y-linked traits are found only in males, e.g., maleness. Some genes are present on both X and Y-chromosomes. These are **X-and-Y linked genes**. As their pattern of inheritance is like autosomal genes, these are also called **Pseudo autosomal genes**.

X being larger has large number of genes, while Y being smaller has small number of genes.

X and Y chromosomes have two distinct regions each due to their linked genes (Fig 17.33).

1. A **pairing region** with common loci of X-and-Y linked genes due to which they synapse during meiosis.
2. A **non-pairing or differential** region with different gene loci of either X-linked or Y-linked genes.

## 17.10 Pattern of sex-linked inheritance:

The pattern of sex-linked inheritance is very specific. It is in a **zigzag** manner. The trait passes from maternal grandfather to daughter and from that daughter to her son. It never comes direct from father to son. As a woman is XX, she carries two alleles for any X-linked trait. She can be homozygous or heterozygous for the trait. But a man being XY can carry only one allele of any X-linked trait on his single X-chromosome. His Y-chromosome does not carry its corresponding allele. He is **hemizygous** for the trait. As Y-chromosome does not carry any counterpart, even a single recessive allele on his X-chromosome can fully express itself. A sex-linked recessive trait can appear in a woman only when she is homozygous for its alleles. That is why chances for a male to be affected by a sex-linked recessive trait are **double** than for a female. This is the reason why **sex-linked recessive traits are more common in males than females**.

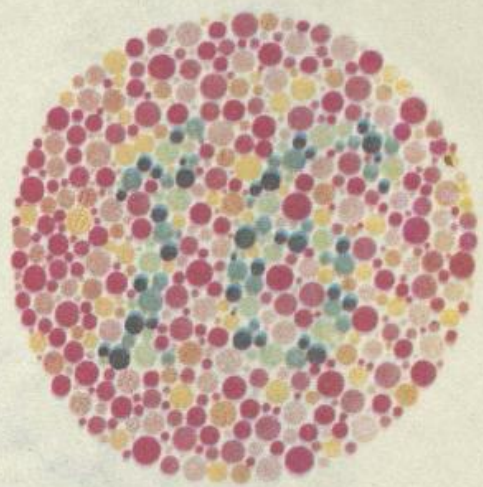
**X-linked recessive** is a trait, which is determined by an X-linked recessive gene. e.g. colour-blindness, Haemophilia.

### 17.10.1 Red-green colour-blindness:

Colour-blindness is a common hereditary disease. Colour-blind person cannot distinguish red from green, because red and green sensitive cone cells are absent in the retina of his eyes. Can you see number 16 in Fig 17.34? If yes, you are normal.

It is a recessive X-linked trait. Gene for normal trait is 'C' and gene for colour-blindness is 'c'. If a colour-blind man marries a normal woman (Fig.17.35), he will pass gene for this trait to all his

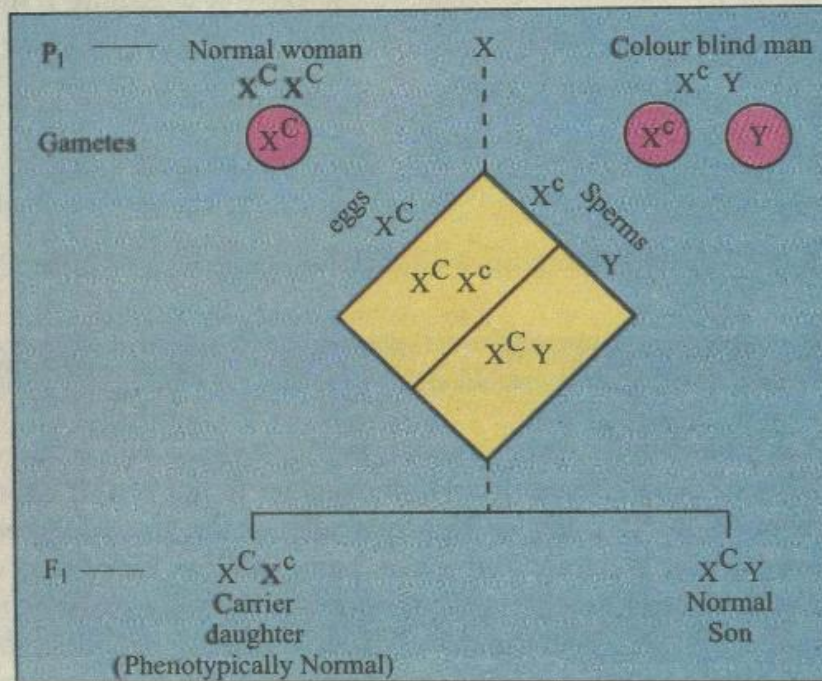
daughters through his X-chromosome. He cannot pass this gene to his sons because sons receive only Y-chromosome from him. His every daughter also receives another X but with the normal dominant



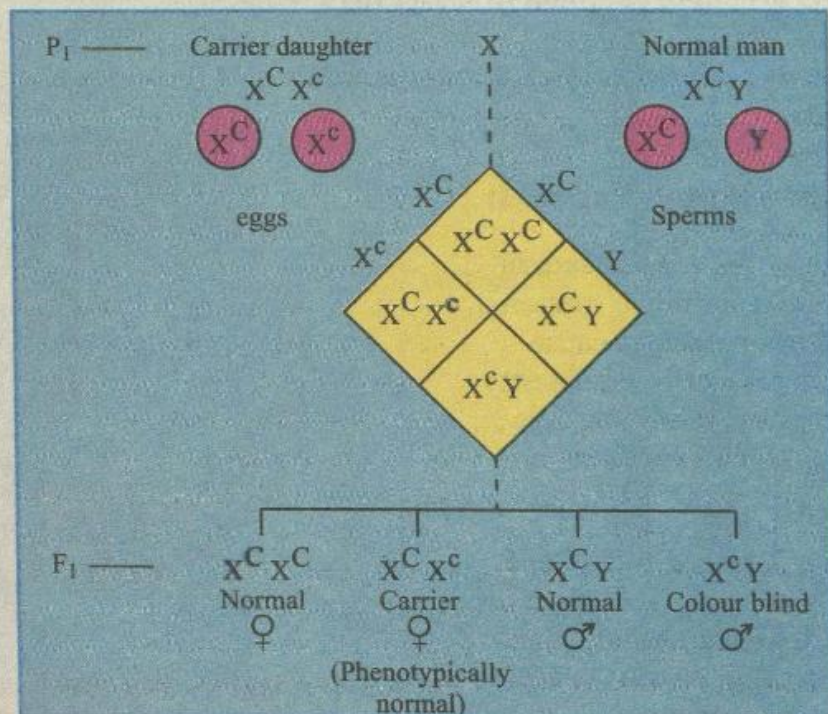
**Fig 17.34: A test for red-green colour-blindness**



allele from her mother. She will be phenotypically normal but heterozygous and a **carrier** for this recessive gene. When she marries a normal man (Fig.17.36), she will pass this trait of her father to that half of her sons who inherit grandfather's X from her. The single recessive allele for colour-blindness expresses successfully in a homozygous son because his Y-chromosome does not carry its counter part. Half of her sons will be normal as they inherit grandmother's X with normal gene. Half of her daughters with both normal X will be normal, but half her daughters will be carrier like their mother.



**Fig 17.35**



**Fig. 17.36**



Have you noted in both these crosses, that not even a single female is colour-blind?

Have you now understood very well why colour-blindness is more common in men than women?

### Activity No. 7: Study of inheritance of colour-blindness in man

Now look at these crosses more carefully again and search for answers to these two simple questions.

Can two normal parents produce a colour-blind son?

Can a normal daughter have a colour-blind father?

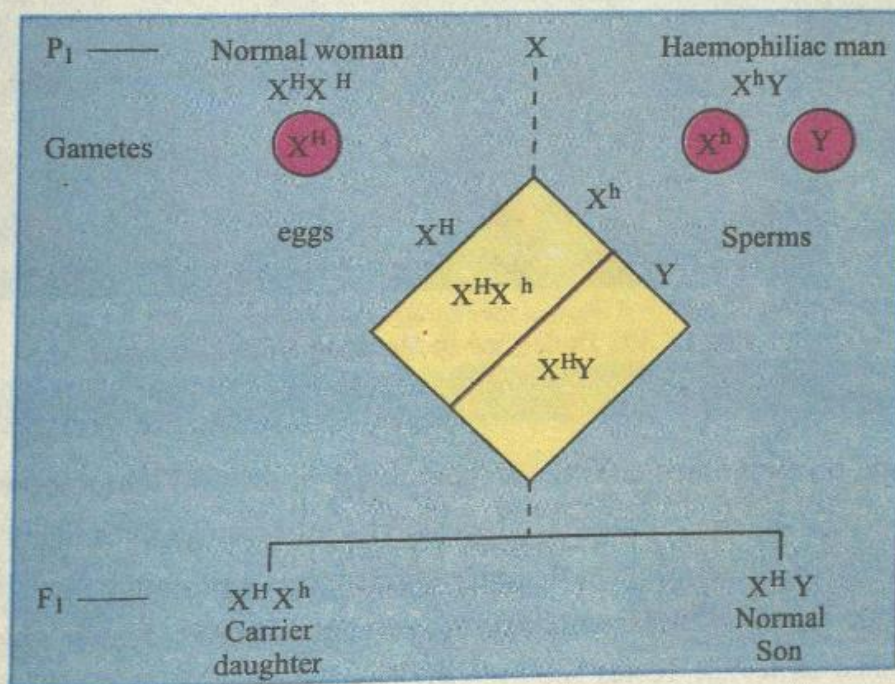
Good, you have found your answers from these crosses. Can you answer two more questions by making their crosses yourself?

1. Can two colour-blind parents produce a normal son?
2. Can a colour-blind daughter have a normal father?

### 17.10.2 Haemophilia

Haemophilia is a rare but more serious **hereditary disease**. It is an X-linked recessive trait. In this trait the blood fails to clot properly after an injury. It is also called **Bleeders disease**. The affected person may bleed to death even from minor cuts.

In a normal person, many blood-clotting factors interact in sequence to make blood clot. Haemophiliac's blood has either a reduction, or malfunction or complete absence of blood clotting factors.

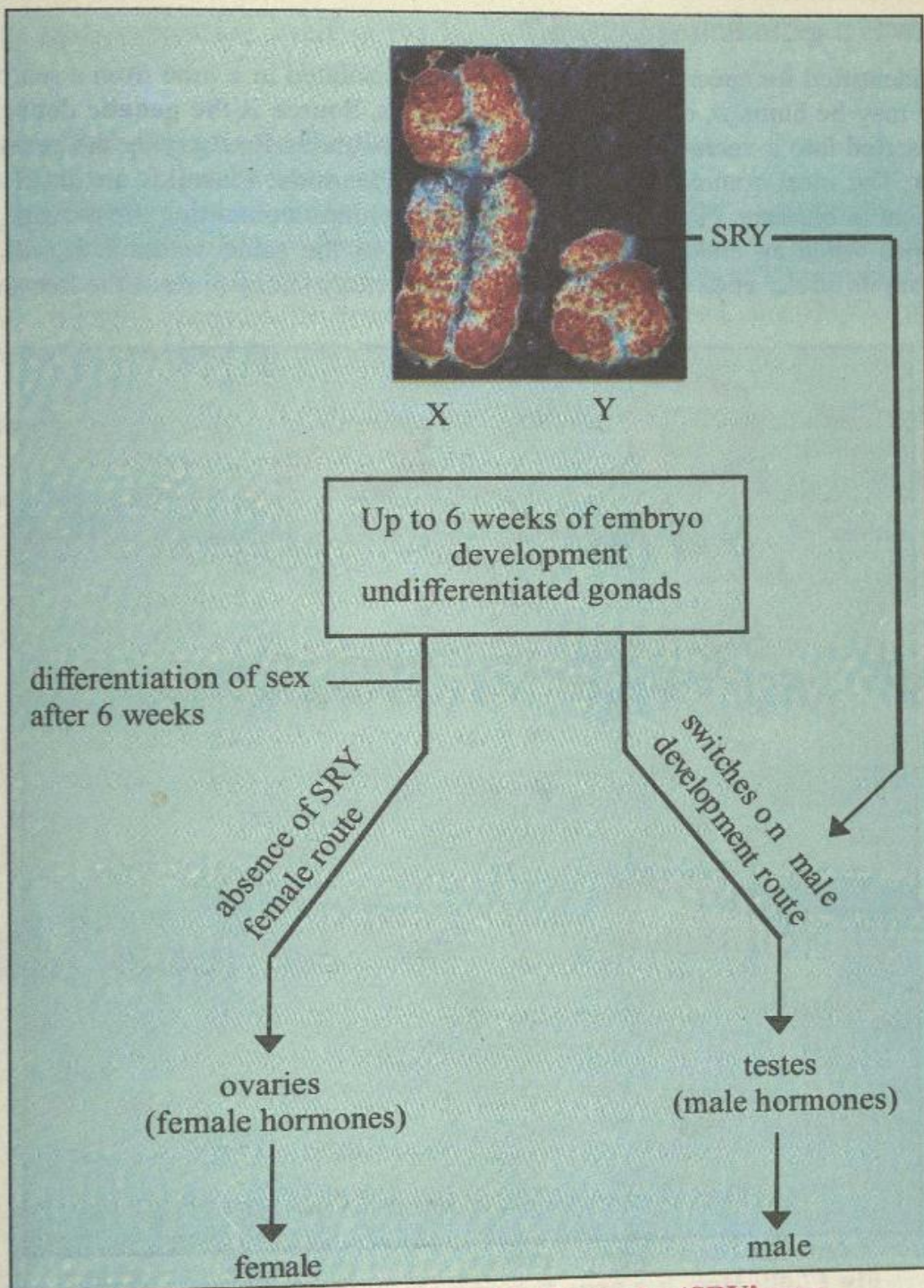


**Fig. 17.37: A normal son can have a haemophiliac father**









**Fig 17.39: Determination of maleness by 'SRY' gene**

## 17.12 Genetic Engineering

Genetic engineering is a technology of gene/DNA manipulation in lab for human welfare. It has brought revolution in all life sciences. DNA has become a molecular toy in our hand. We can remove or insert any piece of DNA at a specific site in a genome. Malfunctioning genes can be cut and removed; healthy normal genes can be introduced.

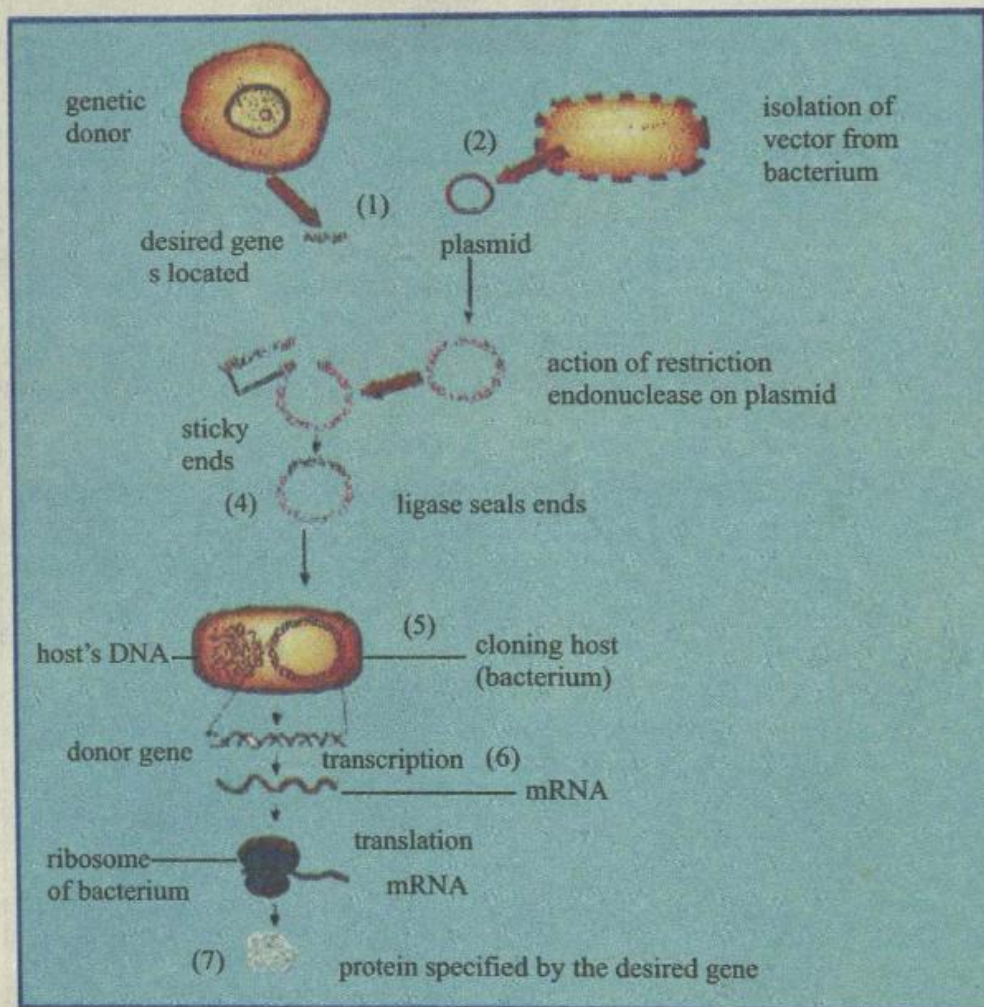
Bacteria make restriction enzymes for their own defence. These enzymes cut unwanted DNA into pieces

DNA is cut by molecular scissors called 'restriction enzymes' or **restriction endonucleases**, which cut DNA by making some bases at the ends unpaired, that makes the end sticky. These are obtained from bacteria.



### 17.12.1 How is a gene transplanted ?

Genes identified for specific proteins are cut and isolated in a tube from a source DNA (Fig. 17.40). Source may be humans, other mammals or plants. Source is the **genetic donor**. The isolated gene is first inserted into a **vector**. Vectors are carrier molecules for carrying the genes to a suitable host bacterium. The most commonly used vectors are **Plasmids**. Plasmids are small circular DNA molecules present in bacteria. Plasmids are placed in a solution containing the desired gene. Imagine what will happen when an endonuclease is introduced in the same solution. It will cut open the plasmid ring with its **sticky ends** exposed. The complementary sticky ends of the free gene will



**Fig 17.40: How is a gene transplanted by genetic engineering.**

attach with open ends of plasmid by forming hydrogen bonds. Plasmid ring will close again. Another bacterial enzyme **ligase** serves as molecular glue. It will seal the ends. Now the gene has been inserted / spliced in plasmid. Plasmid becomes a **recombinant DNA** after incorporating / splicing another DNA.

A DNA molecule formed from DNA's of different organisms is called **Recombinant DNA**.

Now bacteria are chosen as host for cloning this gene. They are exposed to recombinant plasmids. Bacteria take the plasmid in and become recombinant microbes. The bacteria reproduce into a large number of offspring each receiving a copy of the gene. It maintains the foreign gene through multiple generations. In this way multiplication of cloning host amplify the gene. The



transplanted gene starts expressing itself in the host. Bacteria make the protein specified by the foreign gene.

### 17.12.2 Application of Genetic Engineering

Genetic engineering is so useful that several billion dollar industry is based on it. Pharmaceutical companies manufacture hormones, enzymes and vaccines through it. These products cannot be manufactured by any other means. Human insulin for diabetics, Human Growth hormone (HGH) for dwarf children, vaccines for hepatitis B and AIDS patients, and Human interferon for cancer are successfully made from bacteria.

**Gene therapy** is given to cure patients of hereditary disease like sickle-cell anaemia and haemophilia. HbA gene is placed in bone marrow cells of sickle-cell anaemic by vector. The normal gene HbA starts forming its product and the patient becomes normal. Similarly normal gene for factor VIII is incorporated in bone marrow of a haemophiliac.

**Transgenic plants and animals** are being made by introducing desired foreign genes into them. Herbicide resistant cotton, and soyabean, pesticide resistant wheat, viral resistant rice and melon, fungus resistant corn, potatoes and tomatoes with built-in-insecticide have been made successfully. Transgenic animals are genetically deigned to improve meat yield. Today transgenic sheep and goats are secreting human drugs in their milk. Have you heard about Nancy and Ethel?

Nancy is a sheep who secretes human ATT in her milk. ATT cures emphysema, a respiratory disease. Ethel is another sheep who secretes human factor VIII in her milk.

### 17.13 Genetic Engineering Versus Selective Breeding

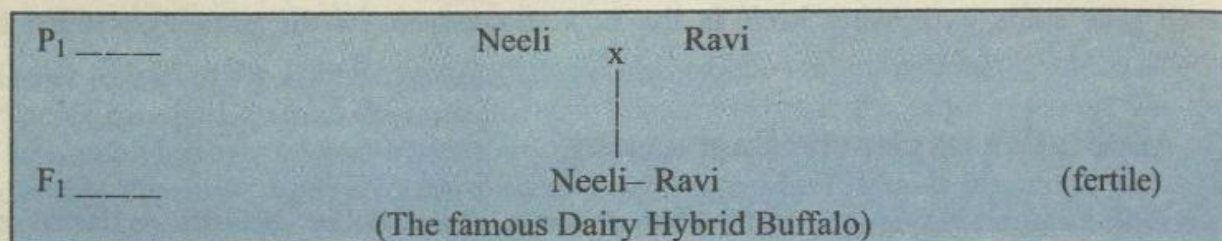
Selective breeding is another practice to improve domesticated animals and plants. We select for breeding those individuals who have characteristics of our choice. We keep on breeding and selecting individuals generation after generation till either we are satisfied with the product or no further improvement can be done.

Starting from a lean cow with very little milk, selective breeding was done in two directions (i) most milk (ii) most meat; one group of cattle breeders ended with large size modern beef cow with meat enough for lots of kebabs, steaks and roasts, the other group ended with modern dairy cow with lots of milk.

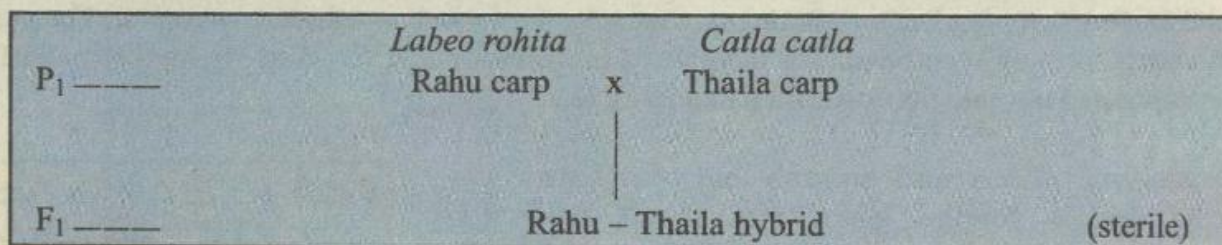
Hybridization and selective breeding have indeed produced a large number of improved varieties of animals and plants like Neeli-Ravi Buffalo, Jersey – Sahiwal cow, Dhani Ox, Kajli sheep, Bital goat, Teddy goat, Rahu –Thaila carp, Broiler and Layer chicken, Maxipak wheat and super kernel Basmati rice but it is a very slow process. It takes months and even years to raise a few generations of animals and plants (Fig 17.41, 17.42).

Genetic engineering has no match. It is a jet – speed process, because it depends on generations of bacteria that take just a few minutes or hours. Moreover the diverse applications of genetic engineering like cloning, gene therapy, finger printing, and gene libraries have absolutely no comparison. Selective breeding is out of fashion, genetic engineering is the most modern.





**Fig 17.41** Neeli is the famous breed of buffalo selected for centuries in the areas of Punjab where river Sutlej flows. Ravi is the best breed of Ravi areas of Punjab. Their natural hybridization in areas of the common belt of the two rivers like Okara has resulted into famous crossbreed Neeli-Ravi.



**Fig 17.42:** Rahu and Thaila are the two major carps of our rivers famous for their delicious white meat. Rahu - Thaila hybrid combines the superior taste of Rahu with larger size and faster growth rate of Thaila.

### KEY POINTS

1. Parents transmit characters to offspring through genes in their gametes. Genes are units of inheritance. These are linearly arranged at specific loci on chromosomes in the form of linkage groups.
2. Mutations produce different alleles of a gene. Crossing over reshuffles the arrangement of alleles in a linkage group. Genetic recombination produces variations that provide raw material for evolution.
3. Genes are short lengths of DNA in chromosomes. DNA is the hereditary material. It stores genetic information in the sequence of its bases in a linear order. It is a unique molecule best suited to store, copy, and transmit biological information from generation to generation.
4. Genotype expresses into phenotype.
5. DNA of every individual is unique.
6. Mendel laid the foundation of genetics by formulating fundamental laws of heredity. He perceived concept of gene at a time when no one knew about chromosomes or DNA.
7. Many autosomal normal human traits and hereditary diseases like Sickle-cell anaemia and Diabetes Mellitus are transmitted in classical mendelian fashion.
8. X and Y chromosomes are sex chromosomes because these have sex determining genes.
9. Pattern of sex-linked inheritance is different from autosomal inheritance. A recessive sex-linked trait like colour blindness or haemophilia zigzags from maternal grandfather through a carrier daughter to a grandson. Y-linked traits like maleness pass directly from father to son only.



10. Genetic engineering is a technology of gene manipulation in lab for human welfare. Its diverse applications have brought a revolution in all life sciences. Though selective breeding has

improved varieties of domesticated animals and plants, the transgenic wonders of genetic engineering have no match.

## QUESTIONS

### 1. Fill in the blanks:

- (i) \_\_\_\_\_ is the passing on of characteristics from parents to offspring.
- (ii) \_\_\_\_\_ is the basic unit of biological information.
- (iii) The chromosomes, which are similar in shape, size and positions of centromere, are called \_\_\_\_\_ chromosomes.
- (iv) The position of a gene on the chromosomes is called its \_\_\_\_\_.
- (v) Partners of a gene pair occupying the same gene locus are called \_\_\_\_\_.
- (vi) \_\_\_\_\_ is the genetic complement in an individual for a particular trait.
- (vii) \_\_\_\_\_ is the genetic material.
- (viii) The four types of nucleotides join to form \_\_\_\_\_ chain of DNA.
- (ix) The two strands of DNA are twisted around each other in the form of a \_\_\_\_\_.
- (x) Adenine pairs with \_\_\_\_\_.
- (xi) During replication each strand of DNA serves as \_\_\_\_\_.
- (xii) RNA is of three types; mRNA, rRNA and \_\_\_\_\_.
- (xiii) \_\_\_\_\_ is an organism that arises from mating between two genetically different parents.
- (xiv) Alternative forms of a single gene are called \_\_\_\_\_.

- (xv) In  $\beta$ -chain of sickle-cell haemoglobin at 6th position glutamic acid is replaced by \_\_\_\_\_.
- (xvi) In 23rd pair a man has \_\_\_\_\_ types of sex chromosomes, but a woman has \_\_\_\_\_ type.
- (xvii) The traits whose genes are present only on X-chromosomes are called \_\_\_\_\_ traits.
- (xviii) The traits whose genes are present on Y-chromosomes are \_\_\_\_\_ traits.
- (xix) The most commonly used vectors in genetic engineering are \_\_\_\_\_.
- (xx) A DNA molecule formed from DNAs of different organisms is called \_\_\_\_\_.
- (xxi) Chromosomes other than sex chromosomes are called \_\_\_\_\_.

### 2. Write whether the statement is true or false. Correct the statement if it is false.

- (i) Each daughter DNA double helix contains both new strands.
- (ii) During DNA replication guanine pairs with adenine.
- (iii) Copying of DNA-coded information into RNA-coded information is Transcription.
- (iv) Pea is normally a cross fertilizing plant.
- (v) Dihybrids are produced by mating parents differing in one contrasting pair of trait.
- (vi) When both the alleles of a gene pair are same, the organism is homozygous for that gene pair.
- (vii) Each block of the Punnet square represents phenotype of the offspring.



- (viii) A heterozygote forms all gametes of the same type.
- (ix) Sickle-cell carriers show no symptoms of disease under normal circumstances
- (x) RBC of HbS/HbS person remain normal disc-shaped in normal  $O_2$  concentration.
- (xi) Both diabetic parents can produce a normal child.
- (xii) In humans, eggs determine sex.
- (xiii) Y – linked genes determine traits found only in males.
- (xiv) X – linked traits pass direct from father to son.
- (xv) X – and – Y linked traits are pseudoautosomal traits.
- (xvi) Restriction enzyme is the molecular glue that seals the ends of a recombinant DNA.
- (xvii) Selective breeding is a jet-speed process as compared with genetic engineering.

**3. Each question is followed by four options. Encircle the correct answer.**

- (i) Who transmits biological information?
  - (a) genes
  - (b) chromosome
  - (c) gametes
  - (d) nucleus
- (ii) What is the diploid ( $2n$ ) no. of man?
  - (a) 8
  - (b) 14
  - (c) 26
  - (d) 46
- (iii) Appearance of a trait in an individual is its
  - (a) genotype
  - (b) phenotype
  - (c) karyotype
  - (d) genome
- (iv) Crossing over takes place between;
  - (a) homologous chromosomes
  - (b) non-homologous chromosomes
  - (c) sister chromatids
  - (d) non-sister chromatids
- (v) What condenses into a chromosome?
  - (a) nucleoplasm
  - (b) nucleolus
  - (c) chromatin material
  - (d) cytoplasm
- (vi) Chemical analysis of chromatin shows that it is composed of;
  - (a) protein
  - (b) DNA + protein
  - (c) DNA
  - (d) RNA

- (vii) What make the backbone of DNA molecule?
  - (a) phosphate
  - (b) deoxyribose
  - (c) nitrogenous bases
  - (d) phosphate + deoxyribose
- (viii) Which is not found in DNA?
  - (a) thymine
  - (b) adenine
  - (c) uracil
  - (d) guanine
- (ix) Guanine pairs whom?
  - (a) adenine
  - (b) cytosine
  - (c) thymine
  - (d) uracil
- (x) Which triplet in DNA codes for valine
  - (a) CTT
  - (b) AGU
  - (c) CAT
  - (d) AAT
- (xi) Only RNA contains
  - (a) uracil
  - (b) ribose
  - (c) deoxyribose
  - (d) ribose and uracil
- (xii) Mendel worked on how many contrasting pairs of traits
  - (a) 5
  - (b) 7
  - (c) 10
  - (d) 14
- (xiii) An individual with heterozygous genotype is a
  - (a) heterozygote
  - (b) hybrid
  - (c) homozygote
  - (d) hemizygous
- (xiv) What is the genotypic ratio of offspring of a monohybrid cross?
  - (a) 1:1:1:1
  - (b) 3:1
  - (c) 1:2:1
  - (d) 9:3:3:1
- (xv) Which gene encodes normal  $\alpha$ -chain of haemoglobin?
  - (a) HbA
  - (b) HbS
  - (c) HbB
  - (d) SRY
- (xvi) Which one is the genotype of a diabetic person
  - (a) DD
  - (b) Dd
  - (c) dd
  - (d) none of three options
- (xvii) What is the chance of a diabetic baby born to parents both heterozygous normal
  - (a) zero
  - (b)  $1/4$
  - (c)  $1/2$
  - (d)  $3/4$
- (xviii) What is the Sex-ratio in humans
  - (a) 1:1
  - (b) 2:1
  - (c) 3:1
  - (d) 4:1
- (xix) Who is responsible for determination of maleness?



- (a) x chromosome (b) y chromosome  
(c) autosome (d) SRY gene

(xx) Which type of trait colour-blindness is?

- (a) autosomal  
(b) X-linked  
(c) X-linked recessive  
(d) Y-linked

(xxi) Pick out the x-linked recessive trait.

- (a) haemophilia  
(b) maleness  
(c) sickle-cell anaemia  
(d) diabetes

(xxii) Which traits are more common in men than women?

- (a) x-linked recessive  
(b) autosomal  
(c) y-linked  
(d) x and y linked

(xxiii) What a male can be for an x-linked trait?

- (a) hemizygous (b) homozygous  
(c) heterozygous (d) heterozygote

(xxiv) Which traits do not pass to women?

- (a) autosomal  
(b) sex-linked  
(c) y-linked  
(d) x- and y-linked

(xxv) Pick out the molecular scissors used in genetic engineering.

- (a) plasmid  
(b) restriction endonuclease  
(c) ligase  
(d) genetic donor.

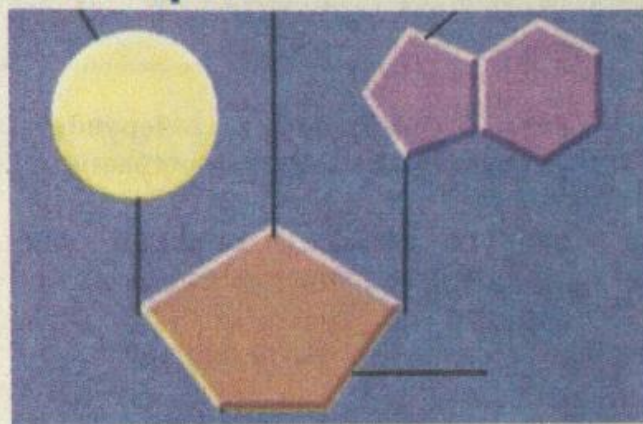
(xxvi) Who secretes human factor VIII in her milk?

- (a) Nancy (b) Ethel  
(c) Kajli (d) Neeli-Ravi

(xxvii) Who among these was produced by genetic engineering?

- (a) Jersey-Sahiwal cow  
(b) Dhani ox  
(c) Nancy sheep  
(d) Rahu-thaila carp

4. Identify the diagram below, label its various parts.



Name: \_\_\_\_\_

5. Differentiate between

Gene and allele

Genome and karyotype

Genotype and phenotype

True breeding and hybrid

Monohybrid and dihybrid

DNA and RNA

Linkage and crossing over

X-linked trait and Y-linked trait

Normal and sickle-cell haemoglobin

6. What is crossing over? Explain it with the help of a diagram. Give its significance

7. What are genes? What is the relationship between genes and chromosomes.

8. Describe Watson and Crick model of DNA.

9. What is the significance of base sequence in DNA? What happens when a point mutation takes place?

10. Describe replication of DNA.

11. How do genes function, to make phenotypes?



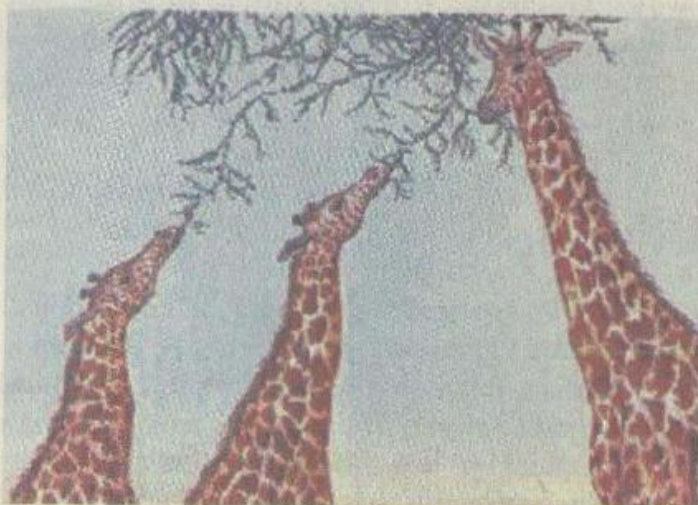
12. Explain Mendel's law of segregation.
  13. What is a test cross. Explain it with an example.
  14. Explain Mendel's law of independent assortment by making a Punnett square.
  15. What are necessary conditions for independent assortment of genes?
  16. How is sex determined in humans.
  17. What is X – linked inheritance? Explain the pattern of inheritance of X – linked recessive trait in man with an example.
  18. Explain the inheritance of a Y – linked trait in man.
  19. Which gene determines maleness in man? How does it determine maleness.
  20. What is genetic engineering? How is a foreign gene transplanted in an organism?
  21. What are various applications of genetic engineering for the welfare of mankind?
  22. Is the sickle-cell phenotype related to  $O_2$  concentration? Describe the autosomal inheritance of sickle-cell anaemia in man.
  23. Why an X – linked recessive trait is more common in men than women?
-



# EVOLUTION

## In this chapter you will learn:

- Definition of evolution
- Concept of variation and its causes
- Role of environment in variation
- Important characteristics of Lamarck's theory of evolution (Lamarckism)
- Salient features of Darwin's theory of evolution (Darwinism)
- Comparative anatomy and artificial selection as evidences in support of evolution.



Almost two and a half million known kinds of organisms live on the earth today. Each organism lives and functions in its own way. Some organisms resemble closely one another while others do not. A horse and donkey are similar in many ways, but each has some features not found in the other. Many of their features are not found in a dog, and each is very different from a frog or a lizard. The great variety of organisms leads to many questions, such as;

- Why are organisms different? How did organisms obtain different features?
- How can many different plants and animals live in the same environment?
- Was the environment always same as it is now?
- If each organism is suited to its environment; what happens if the environment changes?
- Can organisms change along with their environment to survive?
- Were the organisms existing today present in the same form in the remote past?
- Will today's organisms exist thousands of years after?

Because no one has direct knowledge about these questions, answers to them vary. Biologists attempt to find answers to such questions by using scientific methods that is investigations by means of observations, interpretation, hypothesis formation and experimentation.

As a result of scientific investigations biologists conclude that all the diverse forms of life that are now in existence have come into being through a gradual and continual process of modification of ancestral forms. This "descent with modification" is known as **evolution**. Evolution does not lead to finished final product. The evolution modifies all living things and will continue to produce changes in the future also as it has in the present and past.



## 18.1 Variation

You might have observed that human beings have many similarities and differences, for example, in height, weight, colour and other body features. One can differentiate between individuals due to these characteristics. The differences shown by the individuals of one kind of organisms are called **variations**. Variations are due to hereditary and non-hereditary characteristics. Characteristics, which are passed from parents to offspring, are called hereditary characters. e.g. eye colour, hair colour, tongue rolling etc. in human beings. Non-hereditary characters are those which are not transferred to offspring, for example, parent's habits and loss of any body part of a person due to disease, accident etc.

In general the term variation means the differences in characteristics of organisms belonging to the same species in a natural population.

Two types of variations, i.e., continuous and discontinuous, occur in any large population. In **continuous variation**, there are small differences among individuals of the same species and many intermediate forms are seen. So there is a complete gradation of many characteristics of organisms from one extreme to the other in a population. e.g., height in human being. Characteristics showing continuous variations are produced due to combined effects of many genes and environmental factors. In **discontinuous variation**, there are sharp differences among the individuals of a species e.g., tongue rolling, blood groups in man etc, which do not show any intermediate forms. Characteristics showing this type of variations are usually controlled by one or two major genes which may have two or more allelic forms and their phenotypic expression is unaffected by environmental conditions.

A person having extra fingers (six fingers instead of normal five fingers) is an example of discontinuous variation.

Intelligence is an example of continuous variation.

Can you name any other discontinuous and continuous variations in human beings?

As a result of these variations, no two organisms are phenotypically identical. In asexually reproducing organisms, there is a little possibility of variation. Any apparent variation between these organisms is certainly the result of environmental influences. Great variety of variations occurs in sexually reproducing organisms. Crossing over and independent assortment during meiosis and random fusion of gametes in fertilization are the important sources of genetic variation in population. The variation in organisms produced by these sources is not under influence of environment. The environment affects at a later stage. In addition, another important primary source of variation among organisms is **mutation**. These variations which occur due to change in the genetic material that have occurred gradually and continuously since the life started on earth. These variations are heritable as these are passed from parents to their offspring in sexual reproduction. These heritable variations are the raw material for evolution.

## 18.2 Theories of Evolution

The term 'evolution' has a special place in the study of history of life. In terms of organisms, it may be defined as the development of more advanced and complex organism from preexisting relatively simple (primitive) ancestors over a course of time. Various hypotheses have been developed to account for evolution. The outline of the historical background to the development of history of evolution is given in table 18.1.



**Table 18.1. Historical background of development of theory of Evolution.**

| Scientists                              | Contribution                                                                                                                                   |
|-----------------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------|
| Aristotle<br>(384-322 BC)               | Proposed theory of continuous and gradual evolution of life from simple to complex and from imperfect to perfect form.                         |
| Jean Baptiste de Lamarck<br>(1744-1829) | Concept of use and disuse of organs. Inheritance of acquired characteristics; Environment acts on organisms. Phenotypic changes are passed on. |
| Thomas Malthus<br>(1766-1834)           | Human population increases geometrically and food supply increase arithmatically. This relation results in severe competition.                 |
| Charles Lyell<br>(1797-1875)            | Evolution is a long time uniform natural process, demonstrated the progressive history of fossil evidence.                                     |
| Charles Darwin<br>(1809-1882)           | Established a theory called "Evolution by means of natural selection".                                                                         |
| Alfred Russel Wallace<br>(1832-1913)    | Agreed with the theory of Darwin, but excepted humans from the theory.                                                                         |
| August Weismann<br>(1834-1914)          | Suggested acquired characters are modifications of soma (body) cells whereas continuity of race is carried out by germ cells (gametes).        |
| Hugo de Vries<br>(1848-1935)            | Evolution is due to mutations (sudden change). This sudden change results into new species and not by gradual process of evolution.            |

From the above table two main theories of evolution have been discussed here to explain the mechanism of organic evolution.

1. Lamarck's Theory of Evolution (Lamarckism). 2. Darwin's Theory of Evolution (Darwinism).

### 18.2.1 Lamarck's Theory of Evolution (Lamarckism)

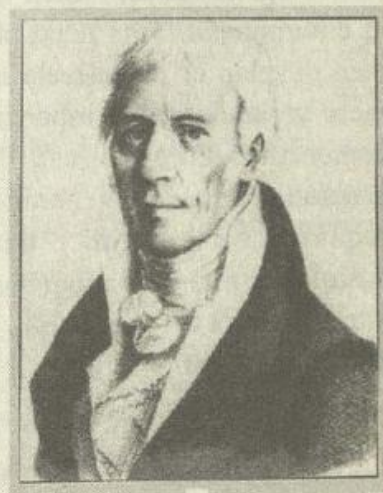
In 1809, a French naturalist Jean Baptiste de Lamarck presented the ideas of evolution in his book, *Philosophie Zoologique*. These ideas about evolution are called as Lamarckism.

There are two important points of Lamarckism.

(i) Use and disuse of organs. (ii) Inheritance of acquired characters.

#### (i) Use and Disuse of Organs

According to Lamarck, in organisms certain changes in the body features are developed by use and disuse of body parts due to biological needs arising out of environmental changes. The organ greatly used develops in its size and organ disused tends to become weaker and can eventually disappear. This statement of Lamarck that



**Fig. 18.1 Jean Baptiste de Lamarck**



use or disuse can produce changes in organs seems correct e.g., the development of muscles in athletes and the development of calf muscles in ladies who wear high heels are common observations.

## (ii) Inheritance of Acquired Characters

Variations in phenotype due to use or disuse of body are called acquired characters as these characters are developed during the life time of an individual. Lamarck believed that these acquired characters are inheritable and are passed on to the offspring from their parents during reproduction.

Lamarckism is illustrated by an example of giraffe's long neck. Lamarck assumed that long necked giraffes evolved from short-necked ancestors. The short-necked ancestors could graze on grasses. When the grasses became scanty the giraffes tried to stretch their necks to reach the top of trees to feed on leaves. As a result of these efforts the giraffes' necks became longer. The same trend continued and the neck went on becoming longer and longer. The giraffes with long necks were able to survive in such an environment. Lamarck believed that acquired characters of long neck in giraffes was heritable and was passed on to the next generation. He believed that gradual accumulation of such changes lead to the evolution of individual which are better suited to their environment.

Regarding disuse of organs, Lamarckism can be described with the help of an example of snakes. Ancestors of modern snakes had four legs with which they used to move on land. In order to escape from enemies the snakes started hiding in holes and creeping in narrow cracks in rocks. In this new mode of life the legs were not used, but muscles of their bodies were used more for creeping. As a result of disuse, the legs were completely lost and body of snakes become elongated and cylindrical. This is how present day snakes have evolved.

Webbed feet of aquatic birds is another example of use of organs, and non-functional wings of Kiwi and Ostrich are the examples of disuse of organs. In human beings appendix (small sac of unknown functions connected to large intestine) and coccyx (fused tail bones) are the result of disuse of organs, as per Lamarck's theory of evolution.

Lamarck's theory of evolution lays emphasis on biological needs, which arise as a result of change in environment. This need produces an urge in the organism to use or disuse certain organs which then develop or degenerate as a consequence thereof. As already discussed Lamarck believed that these variations were inheritable. That these changes were inheritable could not be established. To demonstrate this, **August Weismann** in 1870 cut off the tails of mice over many successive generations. In each generation the mice were born with normal tails. According to Lamarckism, the acquired character (mice without tail) would be inherited. But this was not the case. Weismann postulated that somatic (body) acquired characteristics resulting in phenotypic changes did not directly affect the germ cells (gametes) which are the means by which characteristics are passed on to the next generation.

## 18.2.2 Darwin's Theory of Evolution (Darwinism)

Charles Darwin (1809-1882) while on voyage aboard on a ship (HMS Beagle) made observation about the great variety of birds and reptiles on the Galapagos Islands and their relationship to similar groups on the Ecuadorian mainland.



Charles Darwin was also inspired by the work of his geologist friend Charles Lyell whose major thesis was that geological forces produce a constant changing environment. He also came across an essay on population written by a clergyman and economist Thomas Malthus, who maintained that the human population tend to increase at a much greater rate than does the food supply necessary to sustain the population.

Darwin studied essay outlining a similar theory of evolution by another naturalist Alfred Russel Wallace who observed diversity in plants and animals and their peculiar distribution in South America, Malaya and Indian Archipelago. He was also aware of the practices of plant and animal breeders in producing, in a few generations, the desired traits in domestic animals and plants by artificial selection.

All this knowledge helped Charles Darwin to propose the theory of evolution by natural selection. He presented his theory at a scientific meeting of Linnean Society in London (1858) and published his famous book named "*The Origin of Species by Means of Natural Selection*" in 1859. It created a storm of controversy but generated a favorable band of supporters.



**Fig. 18.2. Charles Darwin.**

The salient features of Darwin's theory of evolution are:

- |                                |                           |
|--------------------------------|---------------------------|
| (i) Overproduction             | (ii) Heritable Variations |
| (iii) Competition for Survival | (iv) Natural Selection    |

### **(i) Overproduction**

All organisms tend to reproduce in geometrical progression ( $1, 2, 4, 8, 16, 32, \dots, 2^n$ ). If all the organisms produced remain alive it would result in millions of organisms of a single species on this earth in a matter of a century even in the case of slow breeders such as elephants.

### **(ii) Heritable Variations**

Darwin noticed that not all individuals of a species when born are alike. He realized that some of the variations were useful to individuals carrying them as these variations helped them to live comfortably in that environment. These individuals could adapt to their environment more than the individuals which did not possess these useful variations.

### **(iii) Competition for Survival**

The available resources of the environment for example, food, water, shelter, etc., are limited. Food can increase in arithmetic fashion ( $1, 2, 4, 6, 8, 10, \dots$ ). We have seen that organisms population increase in geometric progression ( $2^n$ ). Therefore ratio of organisms to food etc; reach unmanageable proportion and leads to a severe struggle for survival. The individuals of a species compete with each other and with individuals of other species to get their food etc.

### **(iv) Natural Selection**

In this competition for survival or struggle for existence, the variants that are better adapted to a particular environment are successful and continue to produce offspring with their adaptive



characteristics. Over time the characteristics, which provide adaptiveness or fitness come to accumulate in the population than those characteristics, which decrease fitness. The greater reproductive success of the better adapted form constitute the natural selection. This means to say that better adapted individuals (with useful variations) are favoured by nature to survive and reproduce, as compared to individuals which are not fit for that environment.

Now question is “How would Darwin have explained the giraffe’s long neck?”

According to Darwin the original giraffe population had variations in the length of their necks, some individuals were with short necks and some with long necks. The long necked giraffe would eat leaves of the trees as well as grass on the ground. When the grass became scarce, the long necked giraffe could obtain more food from the top of trees than short-necked giraffe and were more likely to survive and reproduce. This favourable variation of long neck was inherited by the offspring generation after generation. The present long necked giraffe is the result of process of evolution.

Darwin’s theory of natural selection was reasonable and supported by arguments that is why it was accepted by many scientists.

A comparison of Lamarckism and Darwinism with example of giraffe’s neck is given in table 18.2.

### 18.3 Evidence of Evolution

There are number of evidences which support the theory of evolution. These evidences are based on data obtained from many sources and in all cases the interpretation shows that evolution does occur.

Evidence for evolution comes from many fields as for example geology, biogeography, comparative anatomy, embryology, artificial selection and molecular biology. However we shall discuss only the evidences from comparative anatomy and artificial selection in this book.

The theory of evolution as proposed by Darwin has been modified in the light of modern evidence from genetics, molecular biology, palaeontology, ecology and ethology (the study of behaviour) and is known as **neo-Darwinism** or **synthetic theory of evolution**. This may be defined as the theory of organic evolution by the natural selection of inherited characteristics

#### 18.3.1 Comparative Anatomy

Evidence from comparative anatomy consists of two major types. One is the underlying similarity of comparable structure of pentadactyl limbs (penta:five and dactyl:digits) in different species (fig 18.3).

The arm of a man, the forelimb of horse, the flipper of a whale, the wings of bird and the

In human body, certain structures are considered vestigial e.g., human appendix, although not concerned with digestion is homologous with functional appendix of herbivorous mammals. The vertebrae of human coccyx are thought to represent vestigial structure of the tail possessed by our ancestors and embryos. Likewise non-functional bones in snakes and whales are thought to be homologous with hipbones and hindlimbs of vertebrates



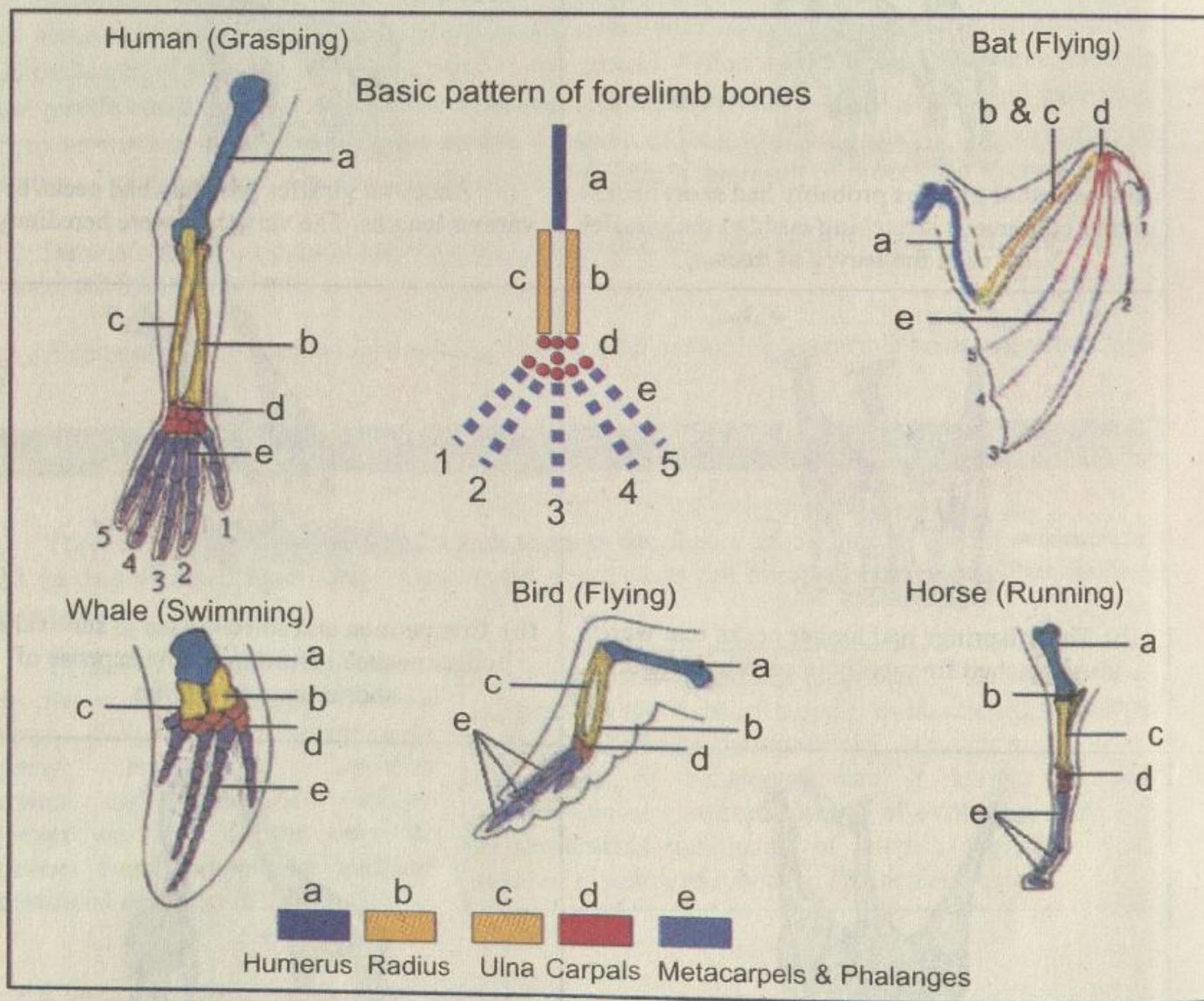
**Table. 18.2 Comparison of Lamackism and Darwinism.**

| Lamarckism                                                                                                                                                                                                               | Darwinism                                                                                                                                                                                                       |
|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
|  <p>(a) Ancestral giraffes probably had short necks and by continuous stretching enabled the giraffes to reach the leaves of trees.</p> |  <p>(a) Ancestral giraffes probably had necks of various lengths. The variations were hereditary.</p>                         |
|  <p>(b) The offsprings had longer necks that were also stretched frequently in search of food.</p>                                     |  <p>(b) Competition and selection led to survival of longer necked offsprings at the expense of shorter necked giraffes.</p> |
|  <p>(c) Eventually the continued stretching of the neck gave rise to modern giraffes.</p>                                             |  <p>(c) Eventually only long necked giraffes survived the competition.</p>                                                  |



forelimb of a bat, all contain similar bones and muscles. Since these structures have different functions but their structural resemblance indicates that they were modifications over a time of some common ancestral structure. The term **homology** is applied to this phenomenon and such organs which are structurally alike but functionally different are known as **homologous organs**. The evolutionary process producing these organs is called **divergent evolution**.

The other type is shown by the development of structure with similar function in very different evolutionary lines. This is called **convergent evolution** and is seen in the close resemblance between the legs of insects and mammals and wings of butterflies and birds. These organs are called **analogous organs** and they serve similar functions but have different anatomical origin.



**Fig. 18.3 Pentadactyl limb (center) and its modifications depending on life style of various animals.**

Another source of evidence for evolution in comparative anatomy is the existence of **vestigial organs**. These are the body parts that were presumably functional at an early time in the ancestral form but have since become remnants. The presence of vestigial organs is an evidence in favour of evolution because it would be much harder to account for non-functional vestiges without having been inherited from some ancestor where these were functional.



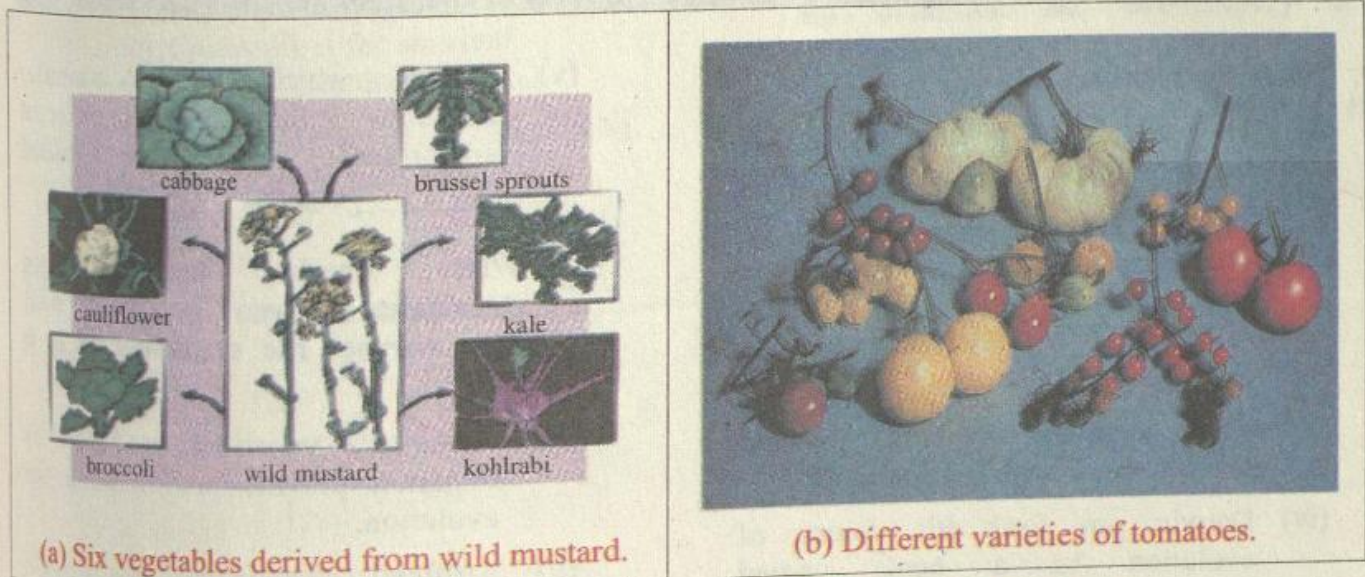
### 18.3.2 Artificial Selection

One of Darwin's most difficult tasks was to convince biologists that selection can produce change within a species. He supported his argument by pointing out that farmers and breeders have developed many varieties of animals and plants through artificial selection. In addition Darwin himself bred pigeons and got variety in colour, size, form and behaviour (figure 18.4) through artificial selection which gave him a clue to the concept of artificial selection but he was unable to appreciate how this could operate in nature. Darwin used this observation to argue that species can change and that its characters are not fixed. He said if change is possible artificially, a similar process of change of selection can also occur in nature.



**Fig. 18.4 Many types of pigeons produced by artificial selection.**

Now a days biologists have produced completely new varieties of animals and plants by artificial selection. It is the process in which organisms with the 'best' or 'desired' traits/ characters are selected and bred with one another so that the traits/characters would be passed on to the offspring. Numerous varieties of animals (e.g., sheep, goats, cows, hens) have been produced by artificial selection to increase production of meat, milk, wool etc. Similarly many plant varieties (fig. 18.5) for example cereals, fruits, vegetables etc. are produced for better quality in production and taste by artificial selection.



**Fig. 18.5 Many varieties of plants produced by artificial selection.**



## KEY POINTS

1. Evolution is the process of gradual change in living things with the passage of time.
2. Individuals vary from one another and these differences among individuals are called variations. There are hereditary, non-hereditary, continuous and discontinuous variations in organisms.
3. Crossing over and independent assortment during meiosis and mutation (gene and chromosome) are the causes of variations.
4. According to Lamarck organisms acquire new characteristics by use and disuse of organs. These acquired characteristics were thought to be inherited by offsprings.
5. Darwin proposed the theory of evolution by natural selection, which has four salient features i.e. overproduction, inheritable variations, competition for survival and natural selection.
6. Lamarckism and Darwinism are based on different principles. Lamarck's theory says that ancestral giraffes had short necks and by continuous use to reach the leaves of trees, has elongated and adapted whereas Darwin's theory says that ancestral giraffes

had necks of various lengths. With continuous selection, a race of long necked individual was established.

7. The concept that evolution has occurred is supported by comparative anatomy and artificial selection:-
  - (a) Homologous Structures have basic structural similarities, even though the structures may be used in different ways. They derive from the same structure in a common ancestor.
  - (b) Analogous organs are the organs which perform similar functions but have different anatomical origin.
  - (c) Vestigial Structures are non-functional or degenerate remnants of structures that were present and functional in ancestral organisms.
  - (d) Artificial selection is the process in which organisms are selected for production of new organisms with desired characteristics.

## QUESTIONS

### 1. Fill in the blanks.

- (i) The process of gradual change in living things with the passage of time is known as \_\_\_\_\_.
- (ii) The variations that are passed on from generation after generation are called \_\_\_\_\_ variations.
- (iii) In 1809 \_\_\_\_\_ presented the idea that organism evolved through inheritance of acquired characters.
- (iv) Darwin put forth his theory of evolution in a book named \_\_\_\_\_.

- (v) Organs which perform similar functions but have different anatomical origin are called \_\_\_\_\_ organs.

### 2. Write whether the following statements is "true" or "false" and then correct the statement if it is false.

- (i) Hereditary variations produced by mutation provide raw material for evolution.
- (ii) Artificial selection does not provide evidence for evolution.



- (iii) According to Darwin changes in the environment are responsible for bringing changes in characters of organisms.
- (iv) The wings of Kiwi and Ostrich are examples of vestigial organs having no useful function.
- (v) Lamarck proposed the theory of natural selection.

**3. Each question is followed by four options. Encircle the correct answer.**

- (i) Which of the following is not a part of Darwinism?
  - (a) Overproduction
  - (b) Natural Selection
  - (c) Inheritance of acquired characters
  - (d) Competition for survival.
- (ii) According to Lamarck the organs which are used more are:
  - (a) Better developed
  - (b) Less developed
  - (c) Completely lost
  - (d) Remained same.
- (iii) Which one of the following is a part of Lamarckism?
  - (a) Overproduction
  - (b) Inheritance of acquired character
  - (c) Competition for survival
  - (d) Natural Selection.
- (iv) The favourable variation tends to be:
  - (a) Passed on to next generation

- (b) Eliminated
- (c) Remain unnoticed
- (d) None from a, b & c.

**4. Give short answers to the following questions.**

- (i) Define evolution.
- (ii) What do you mean by variation?
- (iii) Distinguish by giving examples:-
  - (a) Hereditary variation and non-hereditary variation
  - (b) Continuous variation and discontinuous variation
  - (c) Homologous organ and analogous organ.
  - (d) Convergent evolution and divergent evolution
- (iv) Name two major sources of variation.
- (v) Give two examples of vestigial organs of human beings.
- (vi) What is artificial selection?

**5. Describe Lamarck's theory of evolution.**

**6. Explain the theory "Evolution by Natural Selection".**

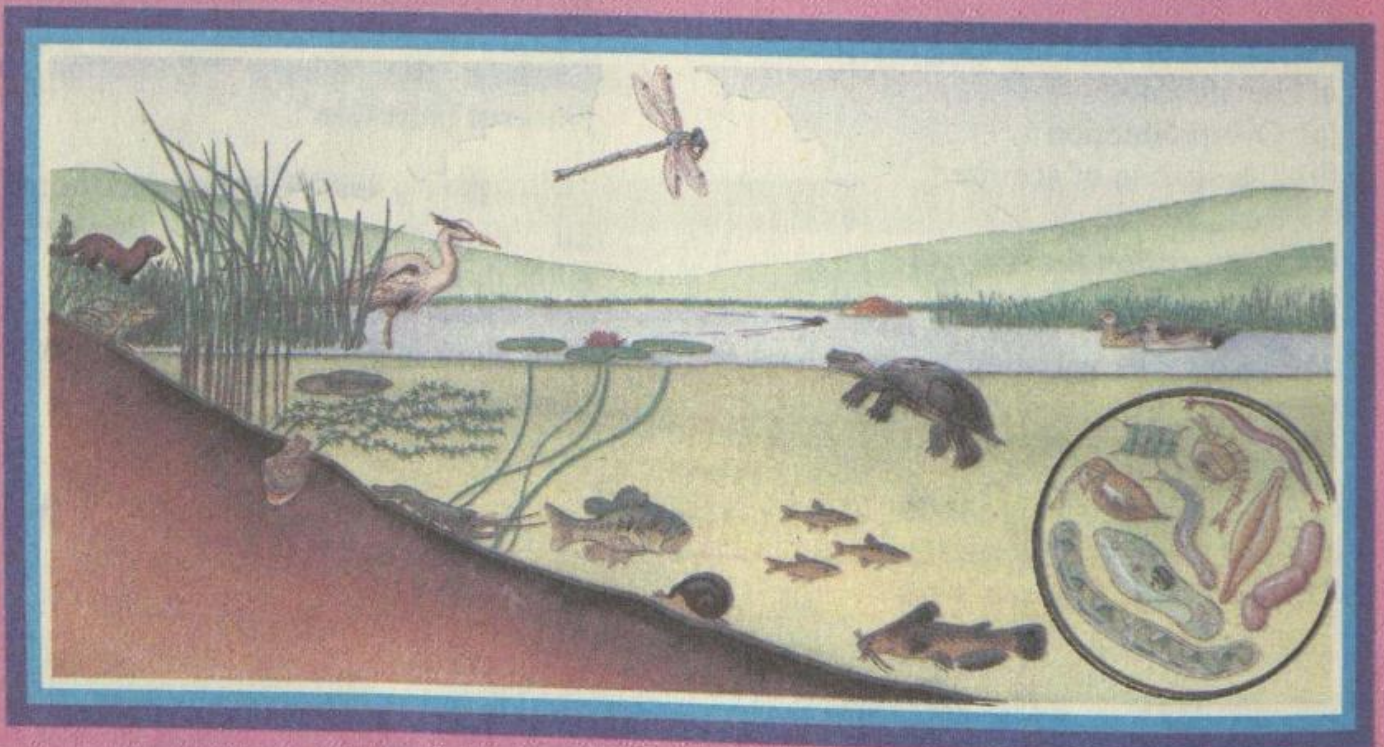
**7. Describe comparative anatomy as an evidence for the theory of evolution.**

**8. How does artificial selection support the theory of evolution? Explain.**



Section  
**7**

# Interrelationship of Organisms with their Environment





# ENVIRONMENTAL BIOLOGY

## In this chapter you will learn:

- Factors that affect an area's ability to support life.
- How changes in the environment might affect organisms.
- The structure of an ecosystem.
- How habitat destruction leads to loss of biodiversity.
- Roles of producers, consumers and decomposer in the ecosystem.
- The concept of trophic levels.
- Food chains and food webs.
- The movement of energy through an ecosystem.
- Ecological pyramids and their relationship to energy flow in an ecosystem.
- The water cycle, the nitrogen cycle and the carbon cycle.
- Predator-prey, host-parasite and symbiotic relationship and their effects on populations.
- The concept of ecosystem balance, and how humans are affecting this balance.



Every thing that surrounds an organism is its environment. An organism's environment, which is a complex of many physical and biological factors, provides every thing the organism needs in order to live. The environment provides food, water, shelter, air, and other resources. If conditions in the environment change, the organism may not be able to survive.

In any environment living organisms show complex relationships among themselves and with their non-living or physical environment. **Ecology** is the study of the relationships of living organisms with each other and their non-living or physical surroundings. Ecology deals with distribution and abundance of life on earth, ecological roles of specific species, interaction among species in communities, maintenance of ecosystems and environmental degradation.

## 19.1 Parts of the Environment

All factors that make up the environment can be divided into two categories: living and non-living. All living parts of the environment are called **biotic factors**. Biotic factors in the classroom

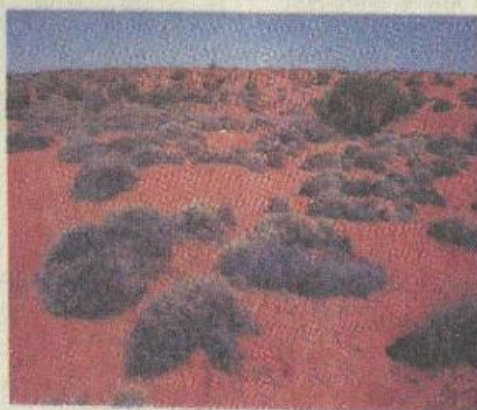


may include only humans and microbes too small to see. If you were passing through a forest, the list of biotic factors in that environment would be larger. The list might include plants, birds, mushrooms, insects and so on (Fig 19.1 & 19.2).



**Fig 19.1. Environment provides every thing the organisms need**

All the non-living parts of the environment are called **abiotic factors**. Abiotic factors include water, soil, and air, as well as temperature, wind, and sunlight. Some of the abiotic factors in an environment may once have been alive, such as your class room's wooden chairs, which came from trees. Because the wood is no longer alive, it is therefore not a biotic factor.



**(a) Aquatic environment.**

**(b) Desert environment.**

**(c) Forest environment.**

**Fig 19.2. Every environment has its own set of characteristics**

## 19.2 Environmental Interactions

Organisms interact with the biotic and abiotic factors in the environment. An organism may be affected by the changes in the environment, and the environment may be affected by the organism. The change in the environment may, in turn, have an effect on other organisms.



### 19.2.1 The Ecosystem

Interactions in the environment result in the establishment of an organized ecological system or ecosystem. An ecosystem is not simply a random collection of organisms and environmental factors. An ecosystem is a highly organized, structured environment in which all parts exist in a delicate balance. Ecosystem can be studied at a variety of levels from individual species to the entire ecosystem.

#### Species

A species is a group of organisms so similar to one another that they can breed in nature and produce fertile off-springs. All the members of a species have similar needs, such as types of food and place of living. Because they have the same needs, members of a species often compete with one another for the resources.

#### Habitat

The type of environment in which a particular species lives is its habitat. For example, the tops of the trees in a pine forest may be the habitat of a species of birds. A shallow, fast moving, cold water stream may be the habitat of a species of trout. A rotting log is an ideal habitat for various species of insects, fungi, and micro-organisms. The habitat provides the appropriate type of food, shelter, temperature, and so on that members of the species need to live (Fig 19.3).

Disturbing the part of an ecosystem that an organism needs to survive is called habitat destruction. Cutting down the trees in a forest is one form of habitat destruction. The destruction of habitats is a serious threat to the survival of many species.



**Fig. 19.3 An organism can live in a particular type of environment**

#### Populations

Population is a group consisting of members of the same species that live together in the same area at the same time (Fig 19.4a). For example, in 1998, 0.56 million people were living in Quetta. We can say that human population of Quetta in 1998 was 0.56 million.

Similarly, all the mango trees in a fruit garden in a particular year constitute population of mango in that fruit garden.

#### Communities

Populations do not live alone in their environments. In any region, many different populations share the same space. These populations interact with one another in a variety of ways. All populations that live and interact in the same environment make up a **community** (Fig 19.4b).

#### Ecosystems

An ecosystem includes all the communities that live in an area, as well as the abiotic factors in the environment (Fig 19.4c). Ecosystems therefore include the water, soil, and climate in the area. A healthy ecosystem includes a wide variety of species in its community. The variety of species in an ecosystem is known as **biodiversity**.

If enough of a particular type of habitat is destroyed, the species that live in the habitat can die out completely, or become extinct. When species become extinct, biodiversity in the ecosystem is reduced.





Fig. 19.4 All the members of a species that live in an area are a population (a). All the populations in the area make up a community (b). Communities together with the abiotic factors form an ecosystem (c).

### Where Have They Gone!

Natural tropical thorn forests once formed one of the most remarkable landscapes of the Indus basin plains in Pakistan. These forests extended from the foothills of the Himalayas (Jhelum) to the Arabian sea (Karachi). These forests (also called Rakhs in the Punjab) were a source of forage, firewood, medicine and fruit. They also supported a thriving wildlife.

As a consequence of habitat destruction due to land reclamation and extensive canal irrigation system, overgrazing, and large scale falling for firewood, these forests have almost disappeared in the Punjab. Some dominant species of this forest system, such as *Salvadora oleoides* (Wan, Peelu) can only be found in scattered remnant patches in the Southern Punjab districts of Bahawalpur, Mazaffargarh etc, or in old graveyards.

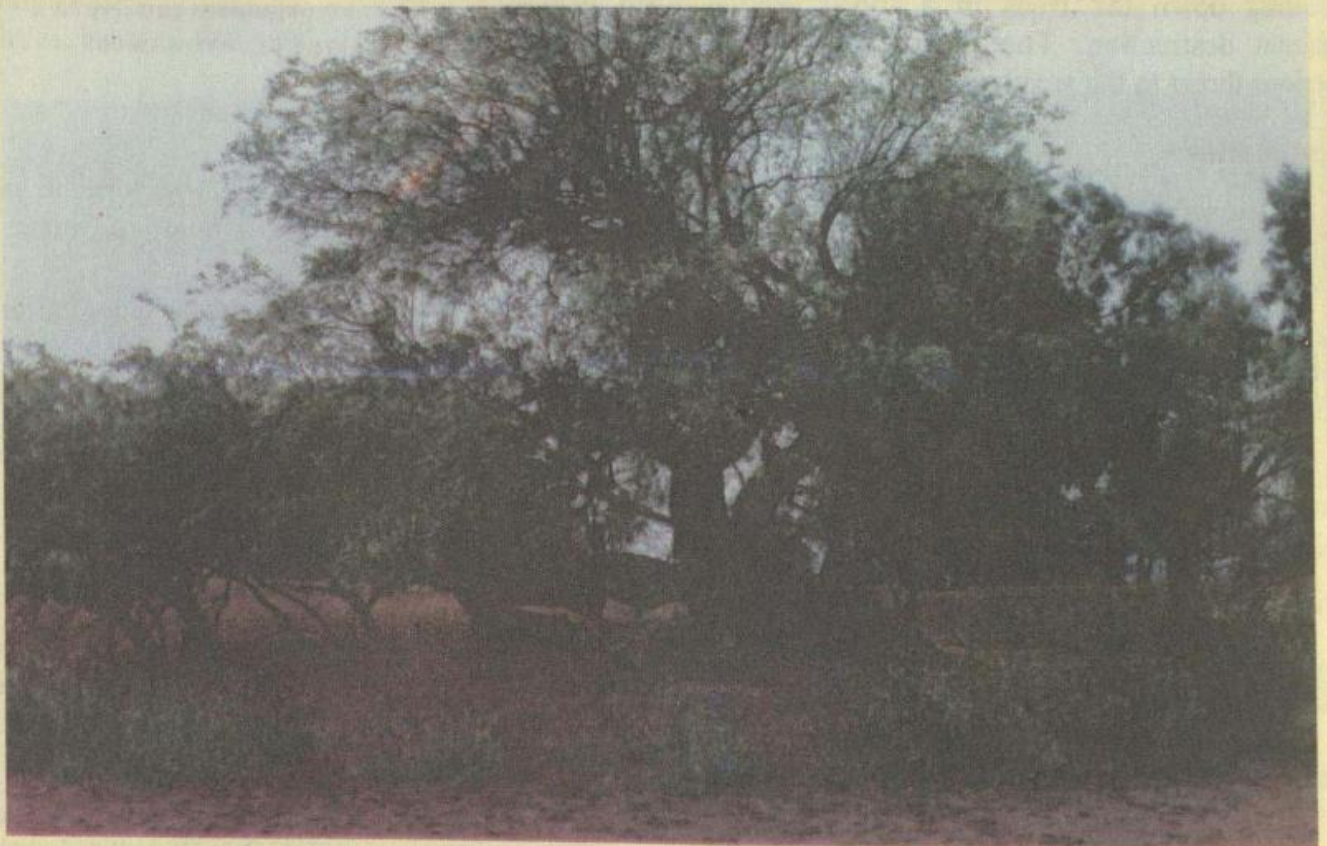


Fig. 19.5 *Salvadora oleoides* (Wan, Peelu)



## The Biosphere

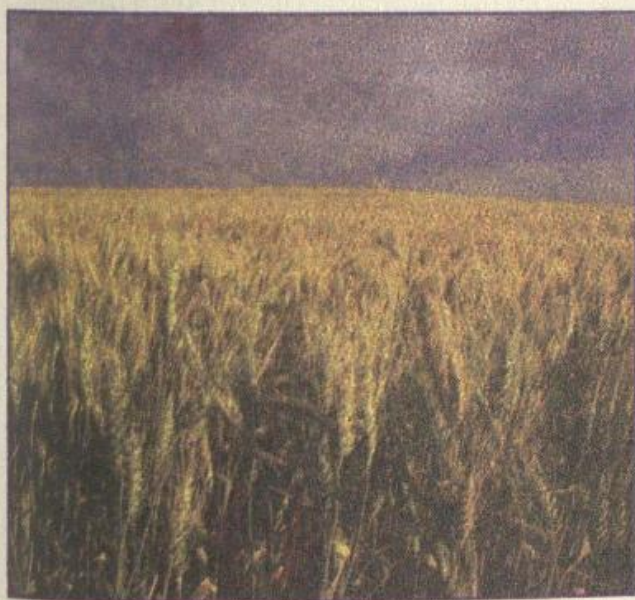
The biosphere is a global ecological system comprising all of earth's communities or ecosystems. In other words it is the largest ecosystem that comprises all the parts of the earth that support life. The biosphere reaches from the floor of the ocean to the tops of the highest mountains. All together, the biosphere is about 20 km (12.4 miles) thick. You may think that this sounds like quite distance, but the biosphere really makes up a thin layer surrounding the planet. If earth were the size of an apple, the layer that supports life would be only about as thick as the apple's skin.

### 19.3 Roles of Living Things (Biotic Components) in the Ecosystem

The organisms of most ecosystems obtain foods in three basic ways: producing, consuming, and decomposing.

#### 19.3.1 Producers

Organisms that make their own food from inorganic molecules and solar energy are called producers. Plants are the most important producers in land ecosystems (Fig 19.6a). In an aquatic



**Fig. 19.6 Major producers in land ecosystems are plants (a). Diatoms are important producers in the oceans (b).**

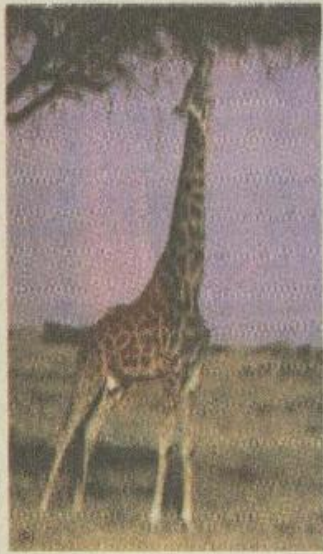
ecosystem, photosynthetic protists are the most important producers (Fig 19.6 b). Nearly all the energy entering the biosphere comes from the sun through photosynthesis.

#### 19.3.2 Consumers

Organisms that can not make their own food and use the food prepared by the producers are called consumers. All animals are consumers, as are fungi and many protists and many bacteria. Consumers obtain energy by ingesting other organisms or by absorbing food molecules. Consumers obtain energy by ingesting other organisms. Consumers obtain food in three basic ways.



Organisms that eat only plants are called **herbivores**. Because herbivores eat producers, they are also called **primary consumer**. Many insects and birds are herbivores, as are grazing animals such as cows, buffalos, goats and giraffes. The bodies of herbivores are adapted to gathering, grinding and digesting plants or other producers.



(a)



(b)



(c)

### 19.7 Consumers may be (a) herbivores (b) carnivores or (c) omnivores

Carnivores capture and eat herbivores or other carnivores. Carnivores that eat primary consumers are called **secondary consumers**, and those that eat other carnivores are called **tertiary consumers**. Lions, snakes, hawks, and spiders are examples of carnivores. The bodies of carnivores are adapted to hunting, capturing, and eating prey.

Some consumers, including human beings are **omnivores** that is, they eat both producers and other consumers. Omnivores act as primary, secondary, or tertiary consumers depending upon what they eat (Fig. 19.7).

#### 19.3.3 Decomposers

Bacteria and fungi that consume the bodies of dead organisms and other organic wastes are called decomposers. They break down a variety of dead organic matter, from the fallen leaves of a tree to the bodies of herbivores and carnivores. Decomposers are crucial to the ecosystem because they recycle nutrients from the organisms back into the environment. Without decomposers, the producers in an ecosystem would quickly run out of nutrients.

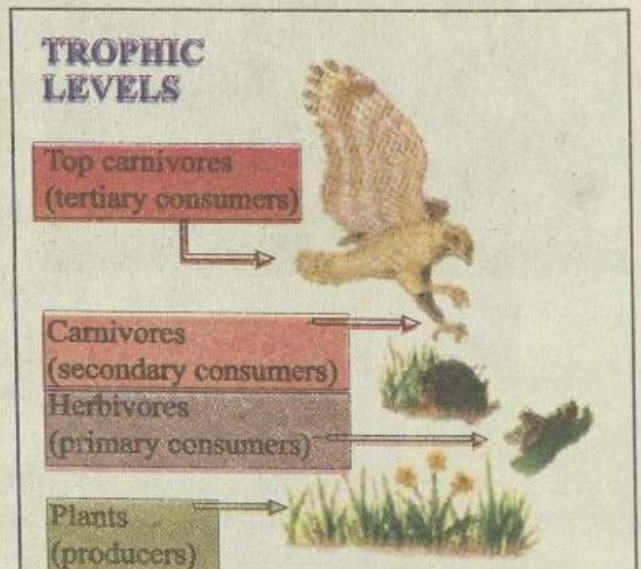


Fig. 19.8 Energy flows when organisms eat one another. The organisms that obtain their energy from a common source constitute a trophic level.



## Trophic Levels

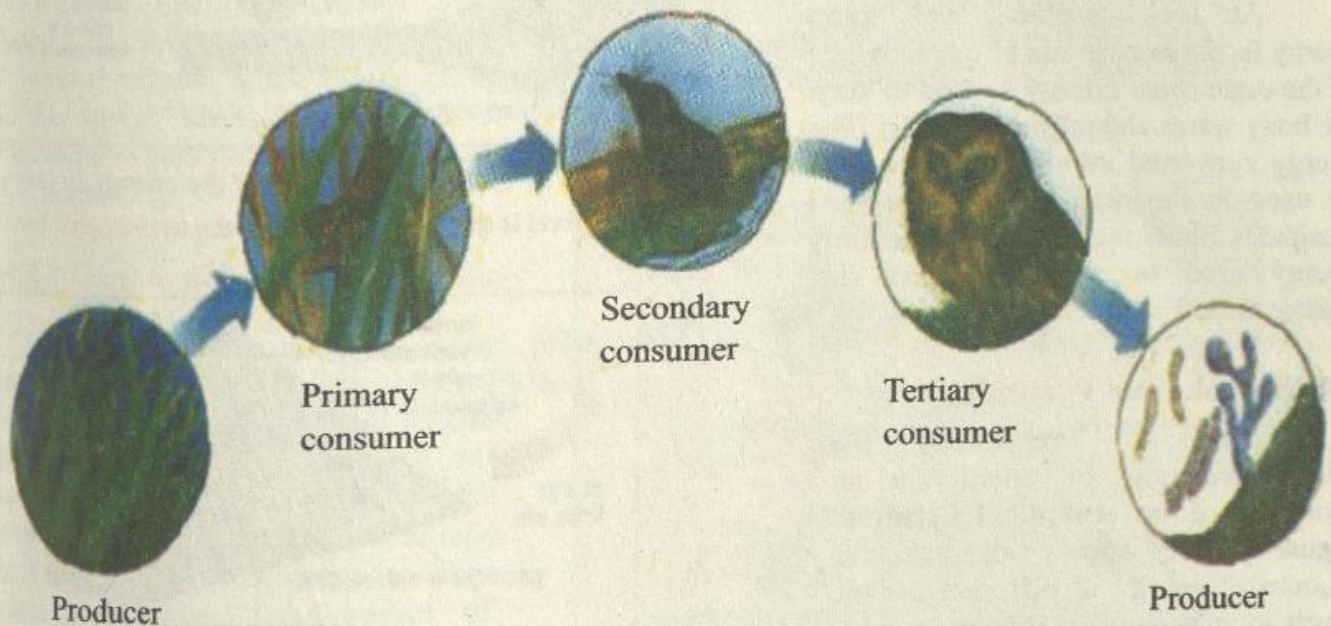
The different feeding levels of organisms in an ecosystem are called **trophic levels**. Producers make up the first trophic level in all ecosystems. Because they make their own food, producers are called autotrophs. Autotrophs are the sole point of entry for new energy into the ecosystem.

Consumers form the second and higher trophic level in the ecosystem. Because they can not produce their own food and must obtain nourishment by eating other organisms, consumers are called heterotrophs. Primary consumers that eat producers form the second trophic level, and secondary consumers form the third trophic level. Omnivores and decomposers feed at all trophic levels. Most ecosystems have three, four, or five trophic levels. Each trophic level depends completely on the level below it (Fig. 19.8).

## 19.4 Flow of Materials and Energy within the Ecosystem

### 19.4.1 Food Chain and Food Web

The feeding relationships among organisms at different trophic levels form a chain, the food chain. A food chain may be defined as a series of organisms that transfer food between the trophic levels of an ecosystem. All food chains begin with producers, which are usually plants in land ecosystems. The food chain continues to herbivores at the next trophic level, followed by one or more levels of carnivores, the carnivores are consumed by decomposers. An example of a food chain is shown in (Fig. 19.9).



**Fig. 19.9 A simple food chain**



No ecosystem is simple enough to be represented by a single food chain or a few simple food chains. Most consumers feed on more than one type of food, and some consumers feed at more than one trophic level. A **food web** is a network of food chains representing the feeding relationships among the organisms in an ecosystems.

A food web includes all the food chains in an ecosystem. An example of a simple food web is shown in fig 19.10. It is important to note that changes in the population of an organism can affect many other populations.

### 19.4.2 Energy Flow

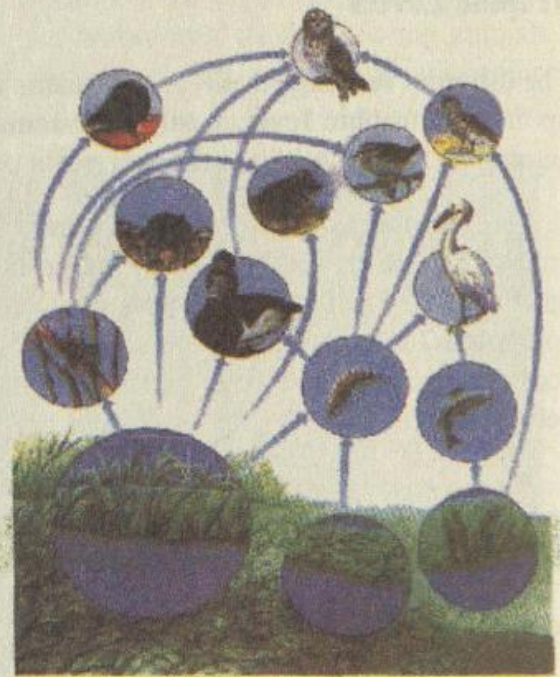
The passage of energy in a one way direction through the ecosystem is known as energy flow. In an ecosystem energy flow occurs in food chains, in which energy from food passes from one organism to the next in a sequence.

Energy from the sun enters an ecosystem when producers use the energy (sunlight) to make organic matter through photosynthesis. Consumers take in this energy when they eat producers or other consumers. In this way energy moves on from one trophic level to the next.

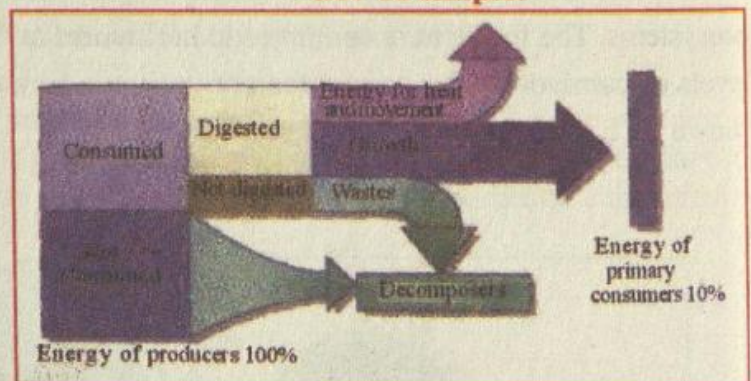
At each trophic level some energy is lost as heat due to the activities of the organisms. Energy is used to keep the body warm and produce motion. The energy converted into heat form cannot be used in the next trophic level and dissipates into the atmosphere. Only energy used to make **biomass** (i.e. organic matter) remains available (Fig. 19.11).

### 19.4.3 Ecological Pyramids

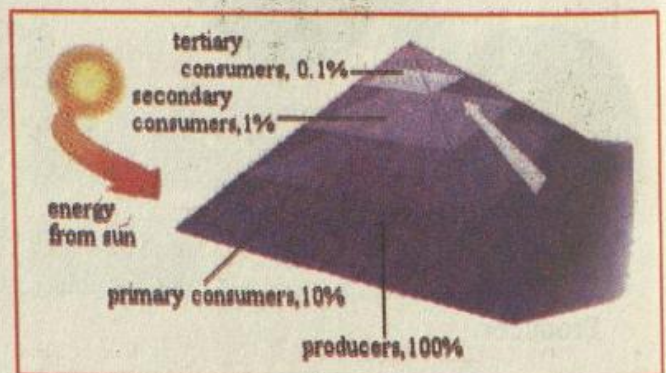
Ecologists represent the relative amounts of energy in an ecosystem in an **ecological pyramid**. Figure 19.12 shows the relative amount of energy in different trophic levels in an ecosystem. The pyramid is divided into sections, each section representing one trophic level. An ecological pyramid can show energy, biomass, or the number of organisms in a food web.



**Fig. 19.10 A simplified food web for an aquatic ecosystem. In nature feeding relationship are not so simple.**



**Fig. 19.11 About 90 percent of the energy in one trophic level is lost before reaching the next trophic level**



**Fig. 19.12 Ecological pyramids. How much of the energy that appears in one trophic level will appear in the next?**



## Pyramid of Numbers

A pyramid of numbers shows the number of organisms at each trophic level in a given ecosystem. In pyramids of numbers, each successive trophic level is occupied by fewer organisms. Thus, the number of herbivores (such as zebras and wild beasts) is greater than the number of carnivores (such as lions) (Fig. 19.13).

## Pyramid of Biomass

A pyramid of biomass illustrates the total biomass at each successive trophic level. Biomass is the total amount of living matter at a trophic level. The pyramids of biomass show a progressive reduction of biomass in the successive trophic levels (Fig. 19.14).

## Pyramid of Energy

A pyramid of energy indicates the energy content in the biomass of a trophic level. These pyramids show that less energy reaches each successive trophic level from the level beneath it because some of the energy at the lower level is used by the organisms to perform work, while some of it is lost (Fig. 19.15).

### 19.4.4 Cycling of Materials in Nature

The chemicals found in living organisms are derived originally from the abiotic components of ecosystems such as soil, water, air. These materials are cycled through the ecosystems and are eventually returned to the environment when waste products and dead bodies of organisms are decomposed by bacteria and fungi. They are available for reuse by organisms.

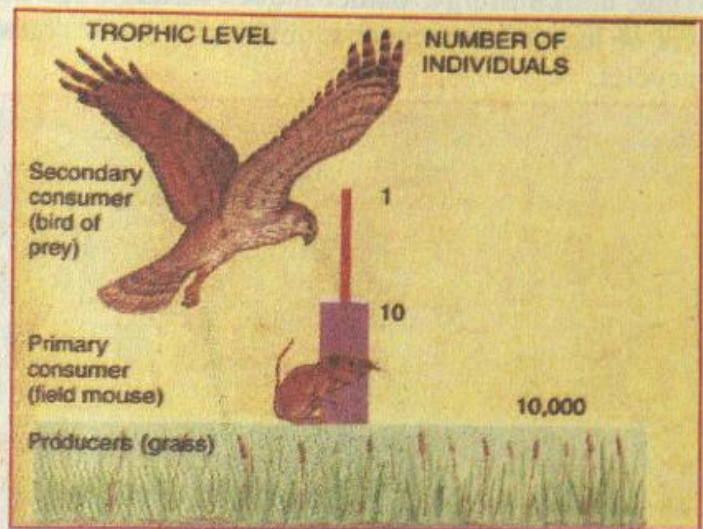


Fig. 19.13 Pyramid of numbers

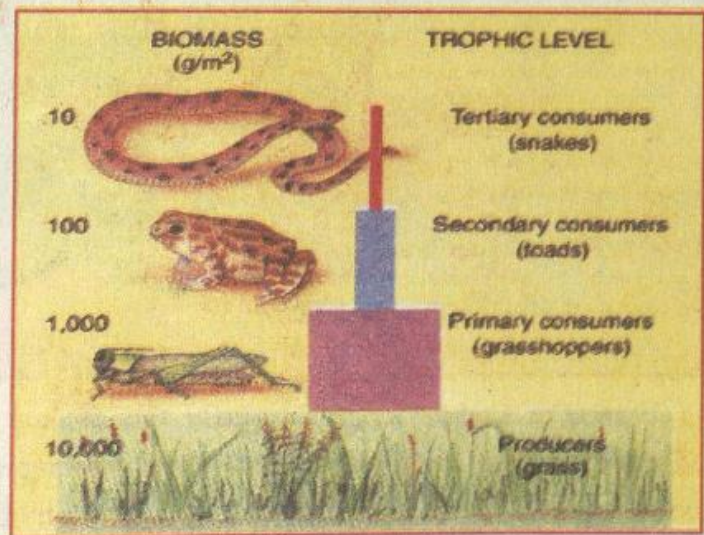


Fig. 19.14 Pyramid of biomass



Fig. 19.15 Pyramid of energy



Thus, unlike energy, matter moves through the ecosystem in cycles. The amount of matter that enters or leaves each cycle is relatively small. This fact is illustrated by carbon, water, and nitrogen cycles.

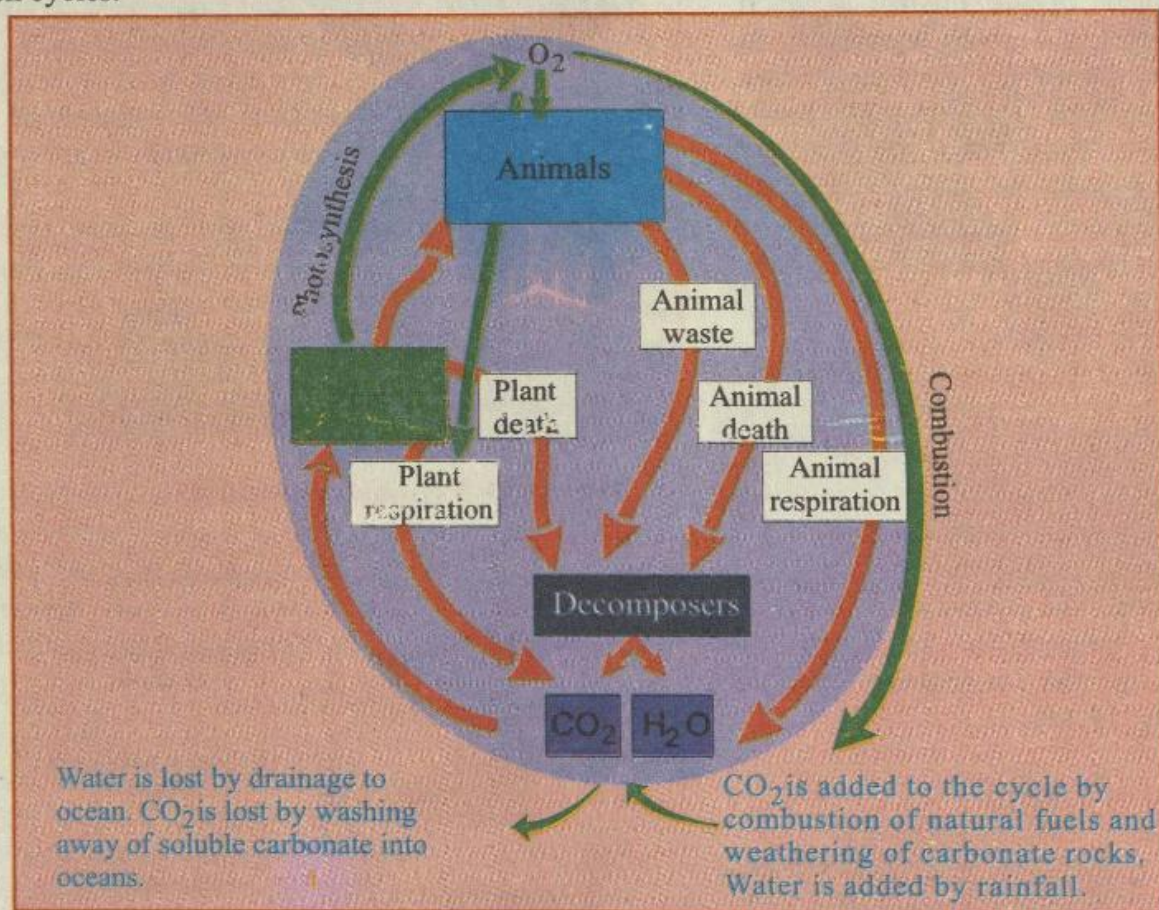


Fig 19.16 The Carbon cycle. Naturally the amount of carbon dioxide used in photosynthesis and released in respiration and decomposition is balanced. However, greater amount of carbon dioxide has been added to the atmosphere by human activities. Do you know how? What may be its consequences?

## The Carbon Cycle

Carbon is an essential constituent of organisms. Carbon from carbon dioxide is utilized by plants in photosynthesis. This carbon becomes a part of the food made by them. The green plants are eaten by the herbivores, which in turn are eaten by the carnivores. Thus carbon is transferred from the plants to the animals. During respiration by plants and animals,  $CO_2$  is released into the atmosphere. Carbon dioxide is also released when dead organisms are decomposed by the decomposers. From the atmosphere it is again returned to the plants and cycle continues (Fig. 19.16)

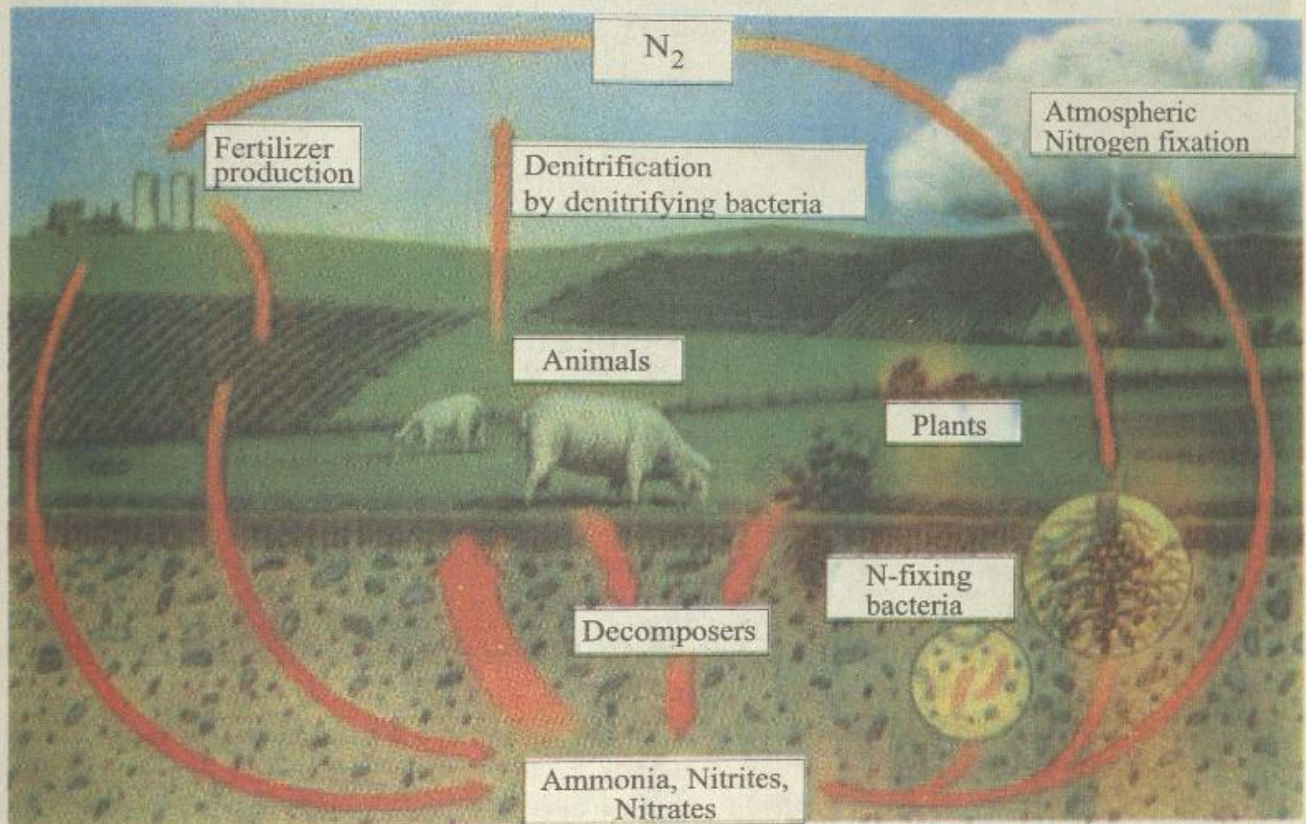
## The Nitrogen Cycle

Nitrogen is important for organism because it is an essential part of proteins, nucleic acids and chlorophyll. Although earth's atmosphere is about 78% nitrogen gas ( $N_2$ ) but organisms are unable to use this molecular nitrogen unless it is converted to certain compounds (such as nitrates)

The nitrogen cycle, in which nitrogen cycles between the abiotic environment and organisms has four steps. The first step in the nitrogen cycle, which is called **Biological Nitrogen Fixation**, involves the conversion of gaseous nitrogen ( $N_2$ ) to ammonia. Biological fixation is carried out by



the activity of nitrogen fixing bacteria in the soil and aquatic environment. Some nitrogen fixation to nitrates also occurs by combustion, volcanic action, lightening discharges and industrial means.



**Fig. 19.17 The nitrogen cycle. All nitrogen originally comes from the atmosphere**

The second step of the nitrogen cycle is **Nitrification**. It involves the conversion of ammonia ( $NH_3$ ) to nitrates. Nitrification is also accomplished by bacteria.

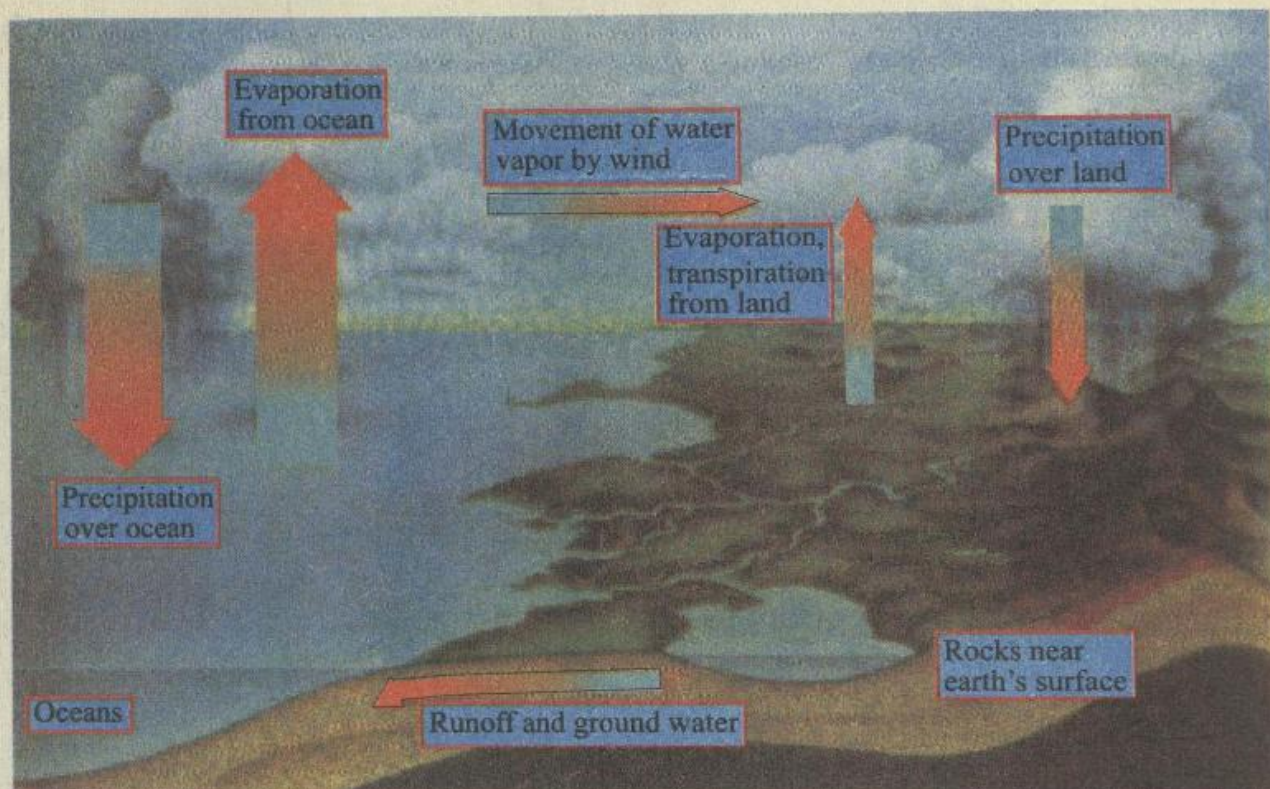
In the third step, called **Assimilation**, plants through the roots absorb ammonia or nitrates and incorporate the nitrogen into proteins, nucleic acids and chlorophyll. When animals consume plant tissues, plant nitrogen compounds are converted to animals nitrogen compounds forming the bodies of animals.

The fourth and final step of the nitrogen cycle is **Denitrification**. During this stage nitrogen containing wastes and dead bodies of organisms are decomposed to ammonia and nitrates. The nitrates are reduced to gaseous nitrogen by the action of denitrifying bacteria. Gaseous nitrogen thus produced escapes to the atmosphere (Fig 19.17)

## The Water Cycle

Water continuously circulates from the oceans to the atmosphere, to the land and back to the ocean. Water evaporates from the ocean surface and from soil, streams, rivers, and lakes in the form of water vapours.





**Fig. 19.18 The water cycle. Most of the earth's surface water is stored in the oceans. Only about 2 percent present in the fresh lakes, ponds, rivers and streams, and in the form of precipitation (rain and snow) is available for our everyday and industrial use.**

In addition, transpiration by plants adds a considerable amount of water vapour to the atmosphere. The water vapour in the atmosphere condenses and forms clouds. It eventually comes down to the land and oceans in the form of precipitation (rain, dew, snow, or hail). Water may evaporate from land and re-enter the atmosphere directly. Alternately, it may flow in rivers and streams as run off water, reaching the ocean. Some water percolates downward in the soil to become ground water. Ground water remains in the ground for hundreds to many thousands of years, but eventually it supplies water to the soil, to streams and rivers, to plants, and to the ocean (Fig 19.18).

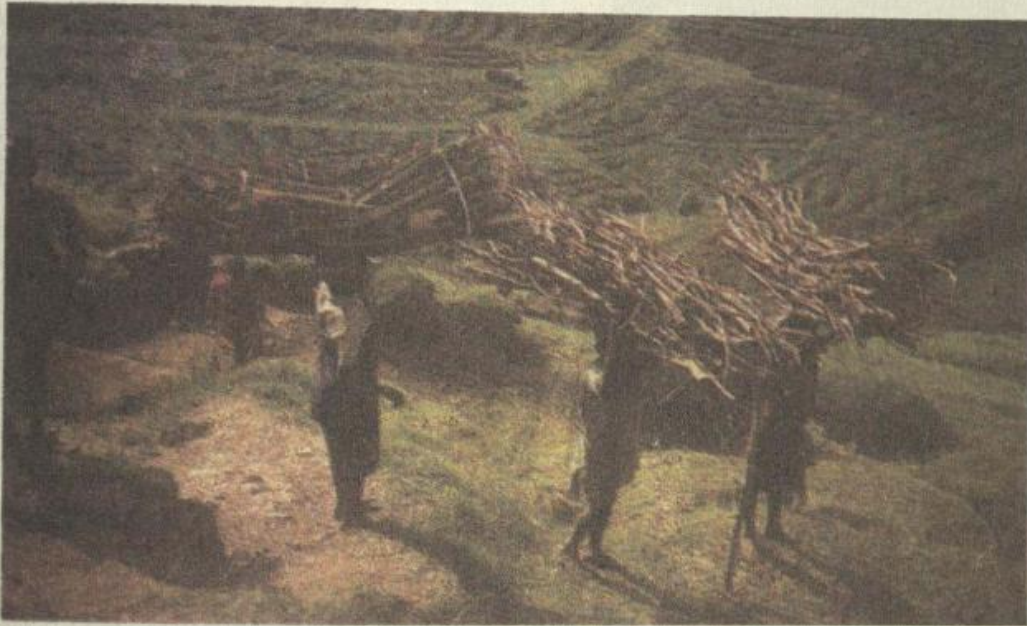
## 19.5 Balance in Nature

An ecosystem is a self-sustaining system. Except for energy (light) it does not require any thing from outside. The system is capable of maintaining itself because of the delicate but complex interactions of its biotic and abiotic components, as illustrated by food webs and natural cycles. Like the human body, the ecosystem has different parts that perform different functions, each crucial to the survival of the whole.

All natural ecosystems are stable. They maintain a state of balance, called equilibrium. If ecosystems are not balanced, they do not survive. An ecosystem gets this stability from the maze of interactions that link its parts. A disruption in one part of the ecosystem, such as a temperature change to a colder climate, is counteracted by changes in other parts of the ecosystem, such as the evolution of adaptation to cold weather. The disrupted ecosystem returns to a state of equilibrium.



Major disruptions cause dynamic changes as the ecosystem adjusts to the new conditions. Some disruptions can destroy whole ecosystems. But a new ecosystem will develop to replace the one destroyed (Fig 19.19).



**Fig. 19.19 Cutting of forests is one form of disrupting the environment and interfering with habitats.**

It is very difficult to understand every detail of how even simple ecosystems function. We understand that changes in one part of a system can trigger changes in other parts. But we cannot always predict how changes in one part of the ecosystem will affect another part.

At present, species are becoming extinct at the fastest rate since earth's known history. The cause of these extinctions is human activity. Humans are also placing many other stresses, such as pollution and deforestation, on global environment without knowledge of the consequences and how will the consequences affect future generations and the global ecosystem in which they live?

## 19.6 Ecological Interdependence of Organisms

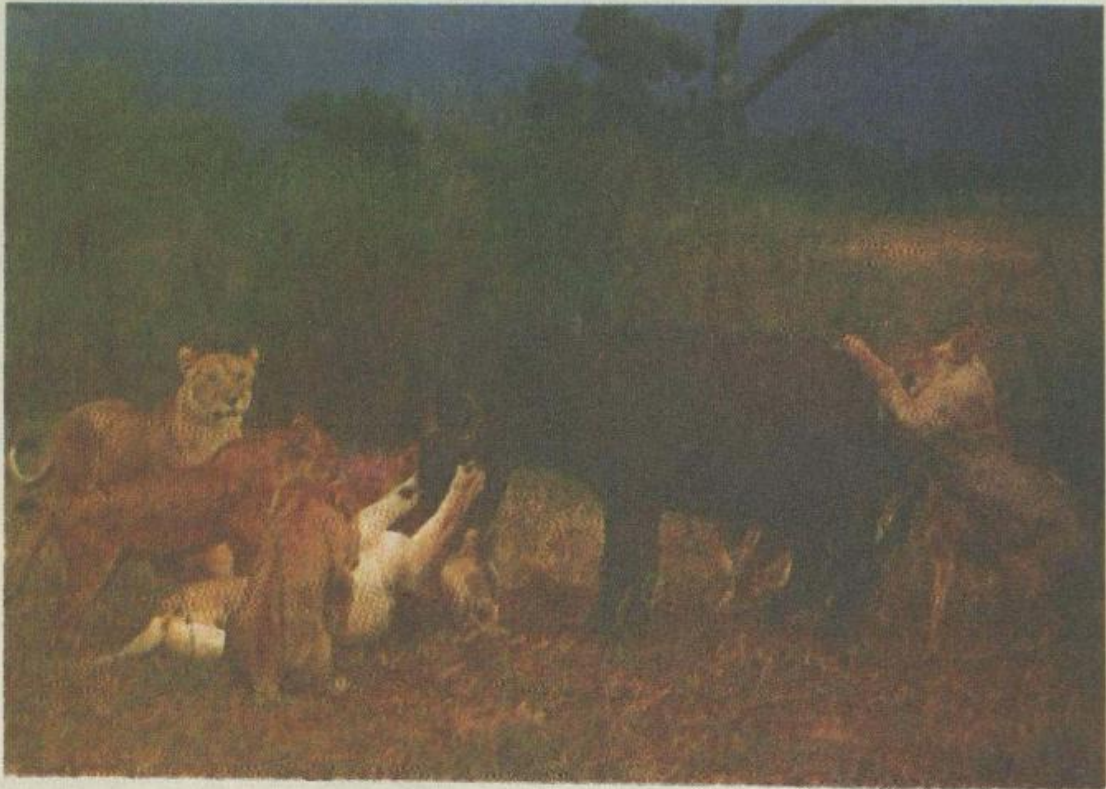
Organisms in ecological communities interact with one another in four major ways.

1. One organism, by its activities, may benefit itself while harming the other. For instance, individuals of one species may kill and eat individuals of other species (predator-prey interaction). One type of individuals may obtain their food from the other but may or may not kill it (host-parasite interaction).
2. Two organisms may mutually harm one another. This type of interaction is common when two organisms use the same resources and the resources are insufficient to supply their combined needs. Such organisms are called competitors, and their interaction constitutes competition.
3. Individuals of two species may develop an intimate, long-term relationship or association (symbiosis). In symbiosis, both participants may benefit from an interaction (mutualism); or one participant benefits and the other is unaffected (commensalism); or one participant benefits and the other is harmed (parasitism).



### 19.6.1 Predation

Consumers that actively hunt other organisms are called predators. The organisms upon which a predator feeds are called prey. A frog that eats an insect is a predator. The insect is the prey. The frog itself is prey to other organisms such as snakes and storks. The predators, in turn, become prey to larger carnivores (Fig 19.20).



**Fig. 19.20** Predators actively hunt and kill their prey

The size of predator and prey populations are closely linked. A large prey population can support more predators than small prey population. If a prey population grows or shrinks, the number of predators changes as well.

### 19.6.2 Symbiosis

The intimate and long-term relationship between two organisms is called symbiosis. It is of three types i.e. parasitism, mutualism and commensalism.

Some organisms do not kill the organism they feed on. **Parasitism** is a type of symbiotic relationship in which an organism feeds on the tissues or body fluids of another. The organism on which a parasite feeds is called the host. A parasite is harmful to its host and may even be fatal. Most parasites, however, do not kill their hosts. Examples of parasites are fleas, ticks, lice, a variety of worms, protists, many bacteria, and all viruses.

A true parasite is adapted to living on or in the body of its host. A parasite depends on its host for many functions. Many parasites cannot perform functions that the host provides for them.

The population size of a parasite is closely related to the population of its host. A large host population can support more parasites than a small host population. Parasite populations are also affected by the density of the host population. Parasites thrive in crowded host populations because the parasite can find new hosts easily.

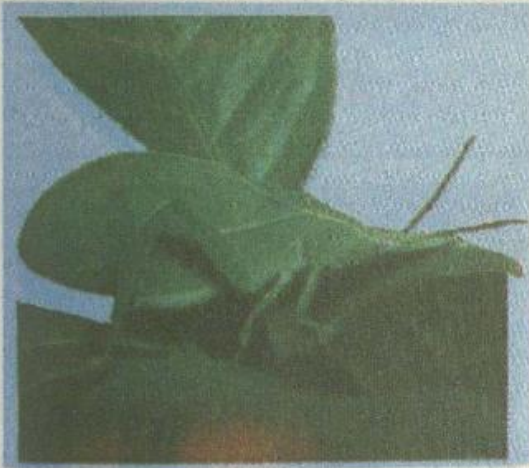




(a)



(b)



(c)



(d)

**Fig. 19.21** As a consequence of predator-prey interactions, prey have evolved a rich variety of adaptations that make them difficult to be captured and eaten. Some of the evolutionary adaptations are toxic hair, bristles or tough spines (a), obnoxious chemicals (b), camouflage (c), and mimicry (d).

### 19.6.3 Competition

Competition occurs when two or more individuals attempt to use essential common resource such as food, water, shelter, living space or sunlight. Because resources are often in limited supply in the environment, their use by one or more individuals or populations decreases the amount available to others.

Competition can occur among individuals within a population, the **intraspecific competition**, or between different species, the **interspecific competition**.

Intraspecific competition may result in:

1. reduced growth and reproductive rates for some individuals,
2. exclude some individuals from better environments,
3. cause the death of some individuals due to non-availability of resources.



Interspecific competition affects individuals in the same way, but in addition, an entire species may be excluded from habitats where it cannot compete successfully. In extreme cases, a competitor may cause extinction of another species.

#### 19.6.4 Mutualism and Commensalism

A relationship where two species live together closely is called symbiosis and the type of symbiosis that benefits one species and neither helps nor harms the other is called **commensalism** (Fig. 19.22). Lichens and other epiphytes growing on trees are examples of commensalism. Similarly, barnacles attached to the backs of whales and turtles get a free ride to better feeding places.



Fig. 19.22 Commensalism



Fig. 19.23 Mutualism

A symbiotic relationship in which both species benefit is called **mutualism**. An example is the relationship between flowers and the insects that pollinate them. The flower provides the insect with food in the form of nectar, and in return, the insect fertilizes the flower. Zooflagellates living in the guts of termites is another example of mutualism. The zooflagellates secrete enzymes to digest cellulose, which termite cannot do. The zooflagellates in return absorb prepared food from the gut. Mycorrhizae, lichens and nitrogen-fixing bacteria in the root nodules of leguminous plants (Fig. 19.23) are other examples of mutualism.



## KEY POINTS

1. An organism obtains all the requirements of life (food, shelter etc) from its environment. The survival of organism may become difficult if the conditions in the environment change.
2. An environment is an interplay of all living (biotic) and non-living (abiotic) factors. Organisms are affected by the changes in the environment, and in turn bring changes in the environment.
3. Interactions among organisms and between organisms and their physical environment result in the establishment of an organised ecological system or ecosystem. All ecosystems are self-sustaining and self-regulatory. So, ecosystems are naturally balanced and possess equilibrium.
4. Changes in one part of the ecosystem lead to changes in some other part (s) of the ecosystem. If disruptions are not catastrophic, they are overcome and the ecosystem returns to its original state. An ecosystem may not be able to bear and absorb large disruption. New ecosystems will replace the old ones.
5. Materials and energy flow through the ecosystem as expressed by food chains, food webs and natural cycles. Flow of material in an ecosystem is cyclic, very few materials enter or leave the ecosystem. On the other hand flow of energy is in one direction only, entering only at the producers level.
6. The relative amount of energy in an ecosystem is represented by ecological pyramids. Less energy reaches a particular trophic level than the level below it. Some energy is lost in the form of heat at each trophic level.
7. Ecological interdependence of organisms results in predator-prey, host-parasite, competitive, and symbiotic relationships.
8. Unpleasant changes in the biosphere are occurring at an unprecedented and faster rate than ever before due to human activity; leading to environmental degradation, pollution and species extinction.

## QUESTIONS

### 1. Fill in the blanks.

- (i) The total amount of the organic matter in a trophic level is called the \_\_\_\_\_.
- (ii) The study of relationships of organism and their environment is called \_\_\_\_\_.
- (iii) All non-living parts of the environment such as water, light, temperature etc are called \_\_\_\_\_.
- (iv) The type of environment in which a particular species lives is called its \_\_\_\_\_.
- (v) Total number of individuals of a species living together in the same area at particular time constitute \_\_\_\_\_ of that species.
- (vi) The biosphere is about \_\_\_\_\_ Km thick.
- (vii) Depending upon what they eat, the \_\_\_\_\_ may be primary, secondary or tertiary consumers.
- (viii) The different feeding levels of organisms in an ecosystem are called \_\_\_\_\_.
- (ix) Omnivores and \_\_\_\_\_ feed at all trophic levels.
- (x) The flow of materials in an ecosystem is \_\_\_\_\_ and the flow of energy is \_\_\_\_\_.



- (xi) All natural ecosystems are balanced and they maintain a state of balance, called \_\_\_\_\_.
- (xii) Competition occurring among individuals within a population is called \_\_\_\_\_.

**2. Each question is followed by four options. Encircle the correct answer.**

- (i) All the members of a species that live in an area make up;  
 (a) an ecosystem (b) a habitat  
 (c) a population (d) a community
- (ii) Habitat destruction can result in a loss of;  
 (a) species (b) community  
 (c) land (d) ecosystem
- (iii) Organisms that make their own food with help of sunlight,  $\text{CO}_2$  and  $\text{H}_2\text{O}$  are called;  
 (a) consumers (b) producers  
 (c) decomposers (d) predators
- (iv) The lowest trophic level of an ecosystem always includes;  
 (a) herbivores (b) carnivores  
 (c) producers (d) consumers
- (v) A network of all the feeding relationships in an ecosystem is called;  
 (a) a food chain (b) a food web  
 (c) a trophic level (d) energy flow
- (vi) Sunlight, temperature, air and water are examples of;  
 (a) biotic factors  
 (b) a biotic factors  
 (c) nutrients  
 (d) mineral resources
- (vii) An organism that actively hunts other organisms is called a;  
 (a) herbivore (b) consumer  
 (c) predator (d) parasite
- (viii) A relationship between species in which one species benefits and the other is harmed is called;  
 (a) symbiosis (b) commensalism

- (c) parasitism (d) predation
- (ix) A relationship between species in which both species benefit is called;  
 (a) parasitism (b) mutualism  
 (c) symbiosis (d) commensalism
- (x) If a disturbed ecosystem goes out of balance and cannot return to a state of equilibrium, the species living there will;  
 (a) move to other places  
 (b) find new resources  
 (c) become extinct  
 (d) face no problem
- (xi) A community and its biotic environment constitutes a (an);  
 (a) biosphere (b) habitat  
 (c) ecosystem (d) food web
- (xii) Which of the following processes increases the amount of atmospheric carbon in the carbon cycle?  
 (a) photosynthesis  
 (b) cellular respiration  
 (c) combustion  
 (d) both a and b  
 (e) both b and c
- (xiii) In the nitrogen cycle, gaseous nitrogen is converted to ammonia by;  
 (a) assimilation (b) nitrification  
 (c) assimilation (d) denitrification  
 (e)
- (xiv) The conversion of ammonia to nitrates is carried out by soil bacteria. This process is called;  
 (a) ammonification  
 (b) nitrification  
 (c) denitrification  
 (d) nitrogen fixation  
 (e)
- (xv) A relationship between organisms in which individual of one species may kill and eat individuals of other species is called;  
 (a) symbiosis (b) competition  
 (c) predation (d) mutualism  
 (e)



**4. Give the short answers to the following questions.**

(i) Define the following terms.

- (a) competition
- (b) symbiosis
- (c) predation
- (d) assimilation
- (e) biological nitrogen fixation
- (f) biomass
- (g) food web
- (h) trophic levels
- (i) habitat
- (k) community.

(ii) Name the fields of study ecology deals in.

(iii) What is meant by habitat? What consequences may be expected if habitat of a species is destroyed?

(iv) What is the importance of decomposers in an ecosystem?

(v) What type of organisms always constitute the lowest trophic level in any ecosystem?

(vi) Write down in sequence the four steps in the nitrogen cycle.

(vii) How does predator prey relationship affect populations?

**4. Explain competition. What are affects of competition on species and communities?**

**5. Discuss symbiotic relationships with examples.**

**6. Describe different types of interactions among ecological communities.**

**7. Write a brief essay on balance in nature, emphasising man's role in disturbing this balance.**

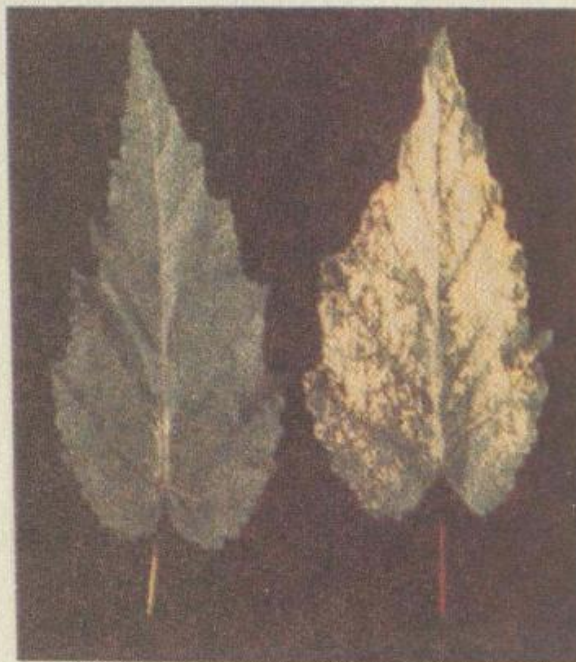
**8. What are ecological pyramids? What do they tell us about flow of materials and energy between different trophic levels?**

**9. Describe ecological roles of producers, consumers and decomposers.**



# MAN AND BIOLOGY

- **In this chapter you will learn:**
- Definition and process of Biotechnology and Genetic Engineering.
- Role of Biology in the economic development of various aspects of human life.
- Biological control of pests.
- Definition, source and control of pollution.
- Role of Biology in the conservation of environment.
- Organisms effecting human health and some common diseases.
- Some insects as vectors of diseases.



Man is a social animal. His demands and problems are increasing day by day. To cope with these demands biologists are investigating day & night. They have introduced many new techniques and technologies, which are proving helpful in solving the problems originated by over population, pollution and microbes.

## 20.1 Genetic Engineering and Biotechnology

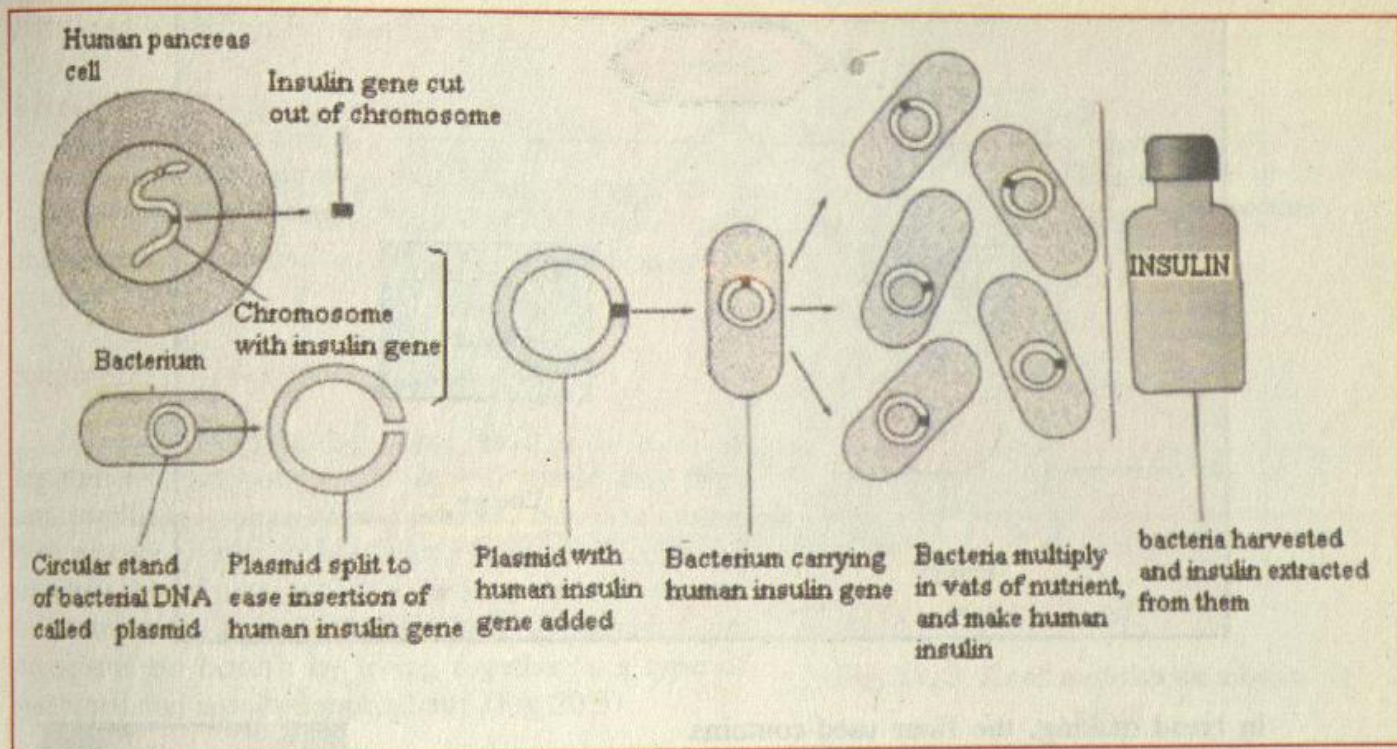
Genetic Engineering is a technique used to transfer useful genes from one organism to another for attaining a specific benefit for mankind. You have already studied it in detail in chapter 17.

### 20.1.1 Transgenic Bacteria and the preparation of Insulin

One of the proteins formed by the process of genetic engineering is Insulin. Insulin is a hormone produced by our bodies, which control the amount of sugar in the blood. People, unable to make insulin suffer from the disease “diabetes mellitus”. They are unable to store glucose as glycogen but excrete it in their urine. Insulin is used to treat such patients. Insulin produced by genetic engineering is exactly the same as ordinary human insulin.

Any organism which acquires a foreign gene is called Transgenic organism.





**Fig. 20.1 The introduction of human gene into a bacterium and production of insulin**

Genetic Engineering is of great importance and has application in agriculture, chemical & drug industries and medicine.

### 20.1.2 Biotechnology

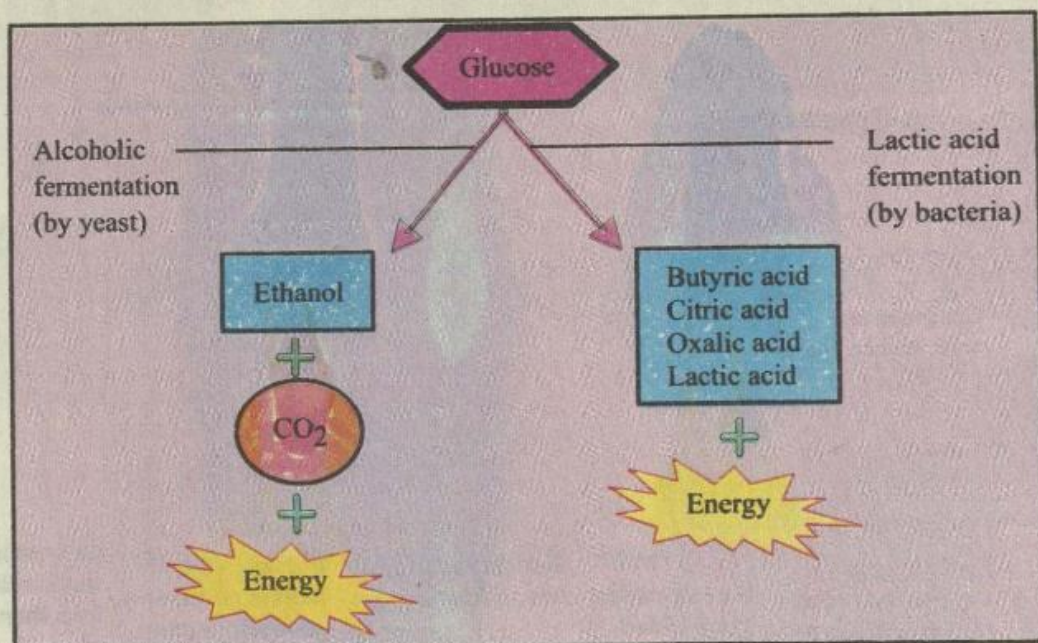
Biotechnology is a large-scale industrial use of biological processes of microorganisms to make substances useful for mankind. The term 'Biotechnology' was introduced in 1970's. Biotechnology is usually linked to genetic engineering and is involved in the production of specific products (e.g. enzymes and hormones) by genetically engineered organisms (Fig.20.1).

The ability of microorganisms to carry out fermentation has long been used to produce foods such as bread, cheese and yogurt. Some other examples of the use of biotechnology are production of antibiotics, single cell proteins and fertilizers.

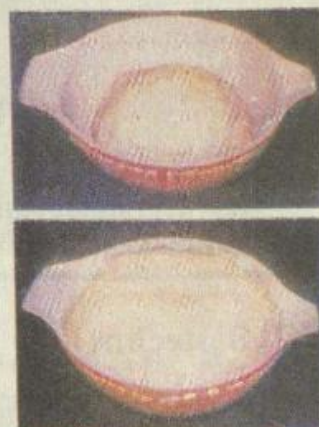
### Fermentation

It is a catabolic process in which partial degradation of sugar occurs without the help of oxygen. Lactic acid fermentation by certain fungi and bacteria is used in the dairy industry to make cheese and yogurt. Alcoholic fermentation is the second type of fermentation. Acetone and methyl alcohol are the by-products of this fermentation. These are commercially important. In baking industry brewing is carried out by yeast.





In bread making, the flour used contains starch, protein and an enzyme amylase. Yeast added in the flour. The flour is mixed with water to form dough. Amylase digests the starch into glucose. Lack of  $O_2$  inside the dough causes the yeast to respire anaerobically. As a result glucose is fermented to alcohol and  $CO_2$ . The  $CO_2$  produced causes the dough to rise and because of this, cavities appear. Alcohol produced evaporates during baking (Fig 20.2).



**Fig 20.2**  $CO_2$  produced by the yeast causes dough to rise

## 20.2 Role of Bacteria and Fungi in Decomposition

Decomposers are saprophytes which feed on faeces and dead organisms. Many bacteria and fungi are decomposers. They secrete enzymes onto their food. These enzymes break down complex organic compounds of the food like carbohydrates and proteins in simpler components with the release of energy. Decomposers absorb only a small amount of energy and nutrients thus produced for their own use. Most of the energy is lost as heat and the remaining materials are released into the surrounding soil, air and water.

The inorganic compounds released during decomposition include gases like  $CO_2$ ,  $H_2S$  and water vapours and salts like nitrates, sulphates, phosphates and potassium ions. These are reused by green plants during photosynthesis and other synthetic processes.

### Nitrogen Fixation

Another important function performed by bacteria is nitrogen fixation. Nitrogen fixation is the conversion of molecular nitrogen ( $N_2$ ) of atmosphere to soil nitrogen in the form of nitrites and nitrates, thus increasing soil fertility.

**Nitrogen is an important component of Protein**



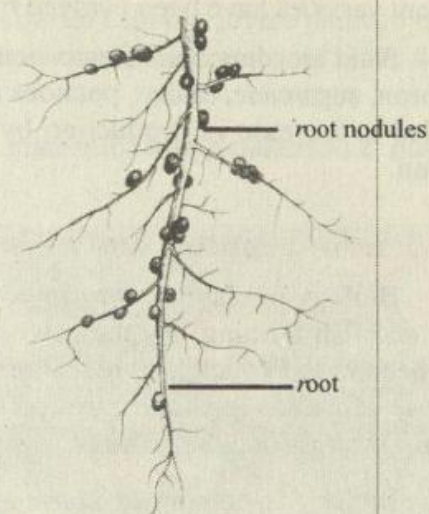
## Nitrogen Fixation By Bacteria

### Free-living Nitrogen Fixers

Bacteria of this type called nitrifying bacteria use carbohydrates from the soil, humus and atmospheric  $N_2$  to make nitrates. These nitrates are used by plants.

### Symbiotic Nitrogen Fixers

Bacteria of this type live inside the roots of leguminous plants (e.g. peas, beans) where they form tiny swellings called **root nodules**. Bacteria obtain both protection and carbohydrate from plant cells and in return release nitrates into the plant tissues and the soil. An association of this kind in which both organisms get benefit by living together is a type of symbiosis and is called mutualism. (Fig 20.3)



**Fig. 20.3 Root nodules on a bean plant**

## 20.3 Application of Biology

The knowledge of Biology is playing very important role in the welfare of human beings. Advance studies in biology specially genetic engineering, plant and animal breeding and biotechnology have influenced man's economic, social and industrial progress. They have enabled man to develop high yielding crops, better strains of livestock and many other developments beneficial to man. They are proving helpful in meeting the demands of rapidly growing population. Some of the contributions of biology in the economic development of various aspects of human life are given below: -

### 20.3.1 Forestry, Fuel, Furniture

Forestry is the business of cultivating trees which provide us fuel, timber and wood products. Timber is used for making furniture. Paper industry is also dependent upon wood. Turpentine and resins are extracted from many of the trees.

Advancement in biology has helped forest cultivators in choosing trees that fit successfully in local habitat. Modern plant breeding techniques have developed various varieties of plants that can tolerate wide range of climatic conditions and are fast growing, in addition to being of high productivity, palatability and nutritional content. So forest cultivators select varieties which satisfy all their requirements.

### 20.3.2 Agriculture

Food and clothing are basic necessities of mankind. With the increase of population man thought of securing more food by cultivating the most desirable plants and domesticating animal breeds. Application of the biological knowledge has enabled scientists to increase yield of crops and to improve quality of fruits and vegetables. In agriculture, cereal crops like wheat, corn, rice have been selectively cultivated and crossed with other varieties to produce super strains

A breed is a collection of individuals within a species which are evolved by selective mating for some definite set of qualities.



capable of giving a palatable high yielding crop in a minimal amount of time. Disease and pest resistant varieties have been evolved by plant breeders.

Plant breeding and selective cultivation has also enabled agriculturists to improve the yield of soyabean, sugarcane, maize, potatoes and almost all other crops and fruits. Biological knowledge has also led to increase in production by the use of fertilizers, better methods of cultivation and crop rotation.

### 20.3.3 Dairy, Poultry and Fish Farming

Biology is playing very important role in the economic development, in the field of poultry, dairy and fish farming. By the use of animal breeding technology, cross breeds of different animals have been raised which provide better protein source in the form of meat and high milk production in the case of cattle, eggs and meat production in the case of poultry and wool & meat in the case of sheep. The cross breeds are more resistant to disease and are more vigorous (Fig 20.4).

Biology is helping to know more about diseases and their cure by studying various disease causing agents like viruses, bacteria and other parasites.

Biological knowledge helps in the development of balanced diet for different animals which is necessary for their rapid and speedy growth. Ideal feed is that which has better food conversion ratio.

### 20.3.4 Sericulture

Sericulture is the production of silk by the activity of worms known as silk worms. This process of rearing silk worms had been crude and laborious and often various diseases of silk worm wipe out all cocoons. Biological knowledge has enabled the farmers to overcome these and many other problems associated with Sericulture.

Adult silk moth female lays eggs, which hatch in three to four days. Young larvae feed on buds and new shoots of mulberry. They grow in size and when fully-grown, silk worm larvae stop feeding and spin a continuous silk thread around it forming a cocoon. After few days cocoons are placed in hot water to kill the Pupa. Workers then pick up one end of the thread and pass it over a reeling machine. These strands are then passed on machine to produce the fabric. Biologists have helped, making revolutionary progress in this field.



**Fig 20.4 A prize bull- the result of improved cross-breeding**

Japanese biologists have developed a wingless variety of silk moth which is easy to handle.

Some varieties which complete 5-6 life cycles in a year have been raised.

### 20.3.5 Apiculture

Domesticating the honeybee for the honey production is known as apiculture. Honeybee is a social insect and lives in large colonies. Honeybees are trimorphic, consisting of queen, drones and workers. The queen bee is larger than the rest and is protected and fed by the workers. It is meant for egg laying. Workers collect nectar and pollen making honey, secrete wax, protect and feed the queen. Drones are male and their function is to fertilize the eggs and they no role in honey formation.

Biological knowledge has led to a better understanding of usefulness of honeybees. Some varieties of domestic honeybees have been imported and their new breeds have been raised by the biologist in Pakistan.



### 20.3.6 Pests and their biological control

A large number of organisms damage useful plants and animals causing severe damage to our economy and even to livestock and public health. Such destructive organisms (insects etc.) are called **Pests**. There are many methods to control the pests: e.g.

- **Primary or cultural control:** Crop rotation should be used instead of mono cultures i.e. planting of only single-species crops again and again.
- **Chemical control:** Chemicals like DDT are used as insecticide. Insects have developed DDT resistant strains. These insecticides also increase the toxicity and pollution, thus their use is now being discouraged.
- **Biological control:** Biological control is the most promising pest control method. The method utilizes natural enemies like predators, parasites and pathogens of pests to control and destroy the pests (Fig 20.5).



**Fig. 20.5 Biological control of pests - here lady bugs are being used to control cottony cushion scale insect on citrus tree**

#### Advantages of Biological Control Method

- They do not pollute the environment
- They do not disrupt and disturb the natural ecosystem.
- They usually provide permanent control of pest population, because pests rarely develop resistance to natural control.

Currently in some developed countries Lace wings and Lady beetles (predatory insects that feed on a variety of other pest insects) are raised commercially. Lace wings are much effective for controlling ball worm population in cotton fields. Recently certain pest pathogenic viruses have also been proved effective in controlling cotton ball worm and corn ear worm.

Pest pathogenic bacteria are also of great importance in this respect. Spores and toxins of the bacterium *Bacillus thuringiensis* are sprayed on leaves, vegetables and flowers. They infect and kill the larvae of at least twenty species of butterflies and moths.

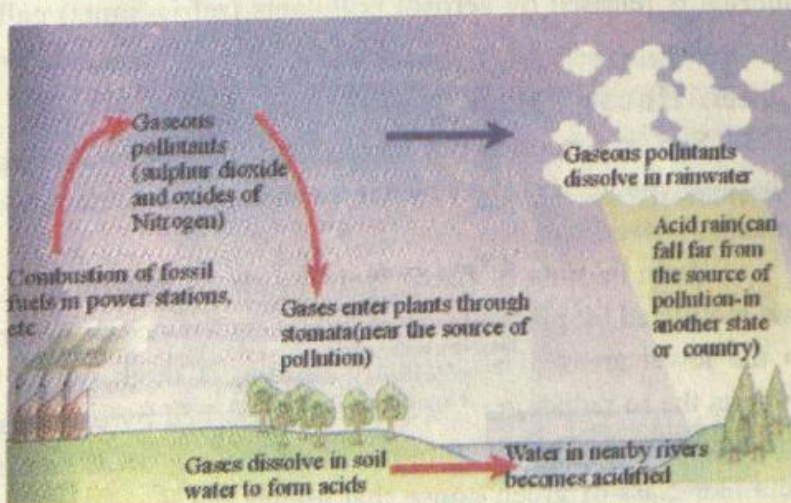
## 20.4 Pollution

Contamination of the environment with waste products and other impurities is called **Pollution**. And the substances whose presence in air, water or soil is harmful to human beings, animals, plants and soil are termed as **pollutants** (Fig 20.6).

### 20.4.1 Types of Pollution

Pollution may be classified as

- Air pollution
- Water & soil pollution
- Sea pollution
- Radiation
- Noise



**Fig. 20.6 Air Pollution**



## Air Pollution

Air pollution is mainly caused by dust, sulfur dioxide, carbon dioxide, carbon monoxide, nitrogen oxides, hydrocarbons and ozone. Common sources of air pollution are;

1. Fuel gases from garbage burning.
2. Exhaust gases from fossil fuels burning in industries and auto motives.

## Water and Soil Pollution

This includes untreated sewage, pesticides and fertilizers, inorganic compounds, waste from radioactive metals, heavy metals like mercury, cadmium, arsenic etc. Sources of water and soil pollution are;

1. Municipal wastes
2. Industrial wastes
3. Agricultural wastes

### 20.4.2 Effects of Pollution on Environment

The environment is being severely damaged by the pollution and is becoming hostile or unfit for the survival of many forms of life including mankind. Following are some of the effects of pollution on environment.

- (i) Sulfur dioxide damages leaves of plants. It corrodes metallic and stone structures.
- (ii) Higher concentrations of carbon dioxide are harmful to animals.
- (iii) Carbon monoxide combines with hemoglobin to reduce oxygen in blood.
- (iv) Oxides of nitrogen corrode metals and stones. They produce photochemical smog that inhibits the plants growth.
- (v) Higher concentrations of ozone reduce air visibility and cause health problems e.g. eyes irritation and headache.
- (vi) Untreated sewage is a source of germs causing cholera and typhoid etc.
- (vii) Densely populated bacteria in water due to pollution consume the oxygen of water, effecting the water animals and even death of fishes.

## Ozone Depletion

Oxygen in the upper atmosphere forms ozone that forms a layer over the earth. This ozone shield filters out the ultraviolet rays of the sun and protects the earth from being damaged.

Ozone shield may be in danger of breaking due to air pollutants particularly nitric oxide and chlorine atoms that attack the ozone layer. Nitric oxides come from emission of aircrafts exhaust and chlorine is released by aerosol pollutants (refrigerants) called chlorofluorocarbons (CFC).

## Green House Effect

Sun rays reach to our earth in the form of visible light and raise the temperature of the earth. This heat energy absorbed by the earth radiates back to space thus temperature of earth remains in balance.

From burning of fossil fuels, much carbon dioxide is produced in atmosphere. About half of this is utilized by plant life or absorbed by the ocean water and the remaining goes on accumulating in the lower areas of atmosphere forming a thick dense layer of carbon dioxide. This thick layer inhibits the re-radiation of heat energy absorbed by earth back to space and adds more temperature to surface of earth. This warming of earth surface is called **Green House Effect**. The thick layer of gas acts like glass of green house that allows the incoming solar radiation but prevents the emission of the outgoing heat waves.



## Biological Oxygen Demands (BOD)

It is a measure of water pollution level due to sewage and other organic matter. Biological oxygen demands (BOD) is the amount of oxygen needed by microbes to decompose the organic matters of water in a fixed period of time, normally 5 days. So large amount of sewage waste in water creates a high BOD, which robs the water of dissolved oxygen.

## Acid Rain

Sulfur dioxide and oxides of nitrogen react with oxygen and rain water readily to form sulfuric acid & nitric acid respectively. Rain containing these acids is known as **acid rain**.

Large amounts of acid rain may cause death of fish in lakes and rivers. Acid rain dissolves aluminum salts in the soil and washes them into lakes and rivers. High concentrations of these salts is poisonous to fishes.

### 20.4.3 How to Control Pollution?

Some of the important measures to be taken for pollution control are;

- (i) *Use of lead free and low sulfur fuel oils.*
- (ii) *Appreciated use of environmental friendly products e.g. natural gas and liquefied petroleum gas in place of high speed diesel and furnace oil.*
- (iii) *Use of wet scrubbers in chimneys of power plants to remove sulfur dioxide.*
- (iv) *Adequate maintenance of auto vehicles for proper ignition.*
- (v) *Installation of heavy process industry far from populated areas.*
- (vi) *Minimum use of non-biodegradable products.*
- (vii) *Use of narrow spectrum biocides.*
- (viii) *Installation of sewage treatment plants.*
- (ix) *Maximum possible arrangements for recycling of wastes.*
- (x) *Use of incinerators to handle municipal and hospital solid wastes.*
- (xi) *Maximum forestation.*

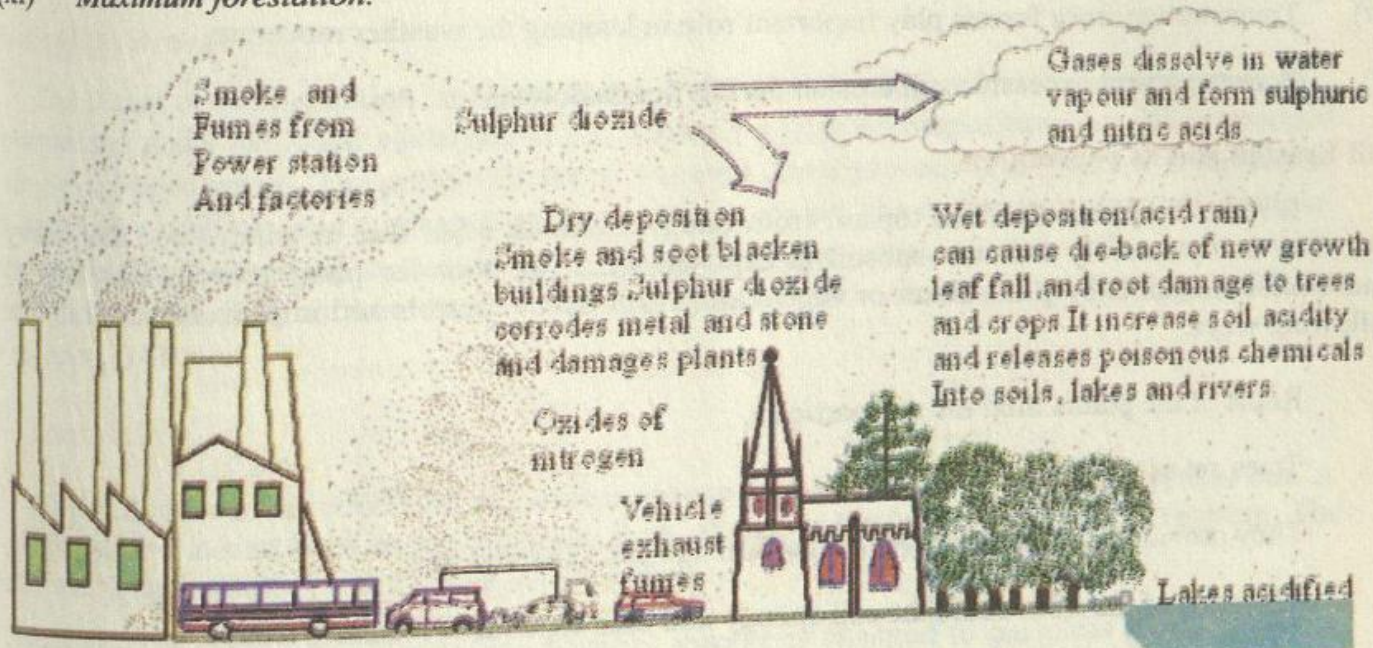
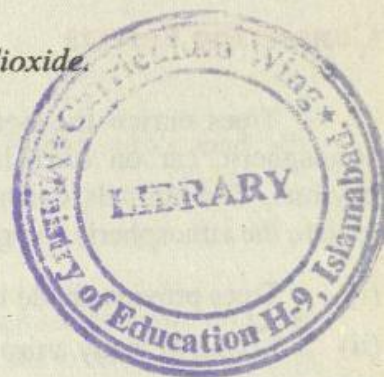


Fig. 20.7 Acid Rain



## 20.5 Conservation

It is necessary to protect and preserve the natural resources to maintain a stable and balanced ecosystem for the benefit of mankind. Natural resources may be renewable or non-renewable resources.

**Renewable Natural Resources:** These are the resources which are never depleted and natural cycles constantly replace these materials. For example air, water, forests, soil, wildlife.

**Non-Renewable Natural Resources:** The resources that are depleted or destroyed and cannot be reused. For example fossil fuels, minerals etc.

### How to Conserve?

Natural resources can be conserved either

- (i) **Directly** by taking care of natural resources.
- (ii) **Indirectly** by controlling human population and consequently reducing pollution level.

### Conserving Forests

Trees enrich the beauty of the nature. They are nature's lungs because they consume the atmospheric carbon dioxide and produce oxygen which is released into atmosphere during the daytime. The animals consume oxygen and deplete the atmosphere of the oxygen, where as trees replete the atmospheric oxygen. Forests save mankind in many ways e.g.

- (i) Trees provide shade to human beings, animals and soil.
- (ii) Living of many animals depends on the forests.
- (iii) Forest cover reduce rate of evaporation from soil.
- (iv) Transpiration from forests play important role in keeping the weather moderate.
- (v) Forests prevent excessive soil erosion during floods & rains

### Soil Erosion and its prevention

It refers to removal of the topsoil from one place to an other due to wind, flood and heavy rain. The comparatively infertile subsoil is exposed which is poor for plant growth. Best way to control soil erosion is by plant cover or vegetation. Plant cover controls and improves the soil in the following ways.

1. Roots of the plants bind the soil particles.
2. Trees act as windbreakers.
3. They provide a protective cover for the soil against wind and rain.
4. The roots of the trees make the soil spongy and thus capable of retaining water.



## Recycling

Recycling is the reprocessing of wastes into a state from which new useful items can be produced. Many substances of common use e.g. steel, paper, glass, plastics and rubbers can be recycled. A good way of pollution control is by reducing the solid waste. Recycling of sewage water and car wash stations may save water wastage. Recycling saves energy and money overall.

## 20.6 Treatment of Organic Sewage

Sewage consists of faeces and urine alongwith water from kitchens, washrooms and shops. It may contain industrial waste too. Sewage contains germs and eggs of parasitic worms so it is necessary to dispose it in such a way that the parasites may not contaminate ground drinking water. Moreover the disease vectors like flies, rats and cockroaches can be infected by these pathogens and can spread the diseases to healthy persons. Treatment of municipal sewage involves the following steps.

### 1. Screening

Large objects such paper, sticks, rags and discarded fruits are removed by passing through series of screens.

### 2. Settling in Grit Tanks

The velocity of screened sewage is reduced by passing it through grits. Particles like sand, silt and small stones settle down.

### 3. Sedimentation

The water is made to remain still for long times. Suspensions and lighter solids settle down as sludge which is taken for dewatering in a separate unit. Where as liquid from tank overflows which is further treated.

### 4. Biological Processing

The liquor of sedimentation tank containing materials is biologically treated. oxygen of air , microorganisms and a particular environment are needed for such decomposition. All this is arranged in a single equipped vessel. The polluted water is pumped into a process tank where it is mixed for hours and hours with **air and activated sludge**. A fast moving chain sets in operation. Bacteria respire aerobically consuming molecules of proteins ,fats and carbohydrates . The protozoa as secondary consumers feed on these bacteria. This decomposition is accelerated by adding fertilizers such as **urea, DAP** etc.

### 5. Sedimentation

The treated water is introduced to a sedimentation tank where activated **sludge** settles out. A part of this sludge is sent back to process tank. Rest of the sludge is taken out for dewatering. The treated water is sometimes disinfected by chlorine gas.

After these stages of treatment, the original sewage is changed to harmless liquid which is drained into rivers and seas. The solid sludge obtained may be used as fertilizer.



## 20.7 Population

Human population means the number of people living in a particular area. The area may be town, a district, a country or world as a whole. The human population grows when more people are born each year than die. The rapid rate of human population is a matter of great concern for the ecologists.

Ever increasing human population is continually using and depleting the natural resources on the earth and upsetting the balance of nature. This rapid growth of population has led to an increase in demand for land. To fulfill this demand forests are cleared and trees are cut down. This is known as **deforestation**. Whenever the land of any region is cleared for any purpose, the natural ecosystem of that region is destroyed which in return results in the destruction of natural habitats and disturbance of the balance of nature.

### Purposes of Deforestation

- **Urban development:** Land is cleared for building, houses, roads, factories etc.
- **Cultivation:** For growing crops.
- **Grazing:** Large open grassland have to be provided for grazing by cattle, sheep etc.
- **Timbers:** Wood is needed for construction, furniture making, paper

## 20.8 Organisms Affecting Human Health

### Microorganism

Very minute living organism not seen without the aid of microscope are called microorganisms. There are numerous microorganism but ones which concern us are germs or disease causing microorganisms (called pathogens). They are found almost everywhere in nature (in air, water and soil), on the surface of objects and living organisms, within the living organisms.

Pathogenic microorganisms are viruses, many bacteria, certain fungi and some protozoan.

### Viruses

Viruses cause disease in living cells and are the smallest disease causing particles known. They are only visible under electron microscope. Chickenpox, measles, poliomyelitis, the common cold, mumps, influenza and AIDS are a few diseases caused by viruses.

### Bacteria

Bacteria are larger than viruses and are visible under the ordinary light microscope. All of the bacteria are not pathogens.

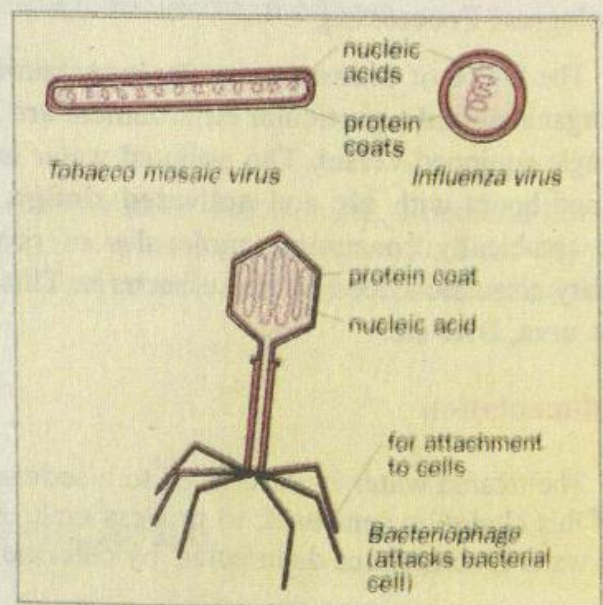


Fig 20.8 Structure of Virus



Some of the diseases caused by bacteria include boils, food poisoning, whooping coughs, cholera, diphtheria, typhoid, bacillary dysentery, TB etc.

### Protozoa

Protozoa are single-celled organisms which vary in size and shape. Very few of them cause disease in humans. Some common diseases caused by protozoa are malaria, amoebic dysentery, some types of ulcers in large intestine, etc.

### Fungi

Very few fungi are responsible for causing human diseases. Most of the fungi are multi-cellular but some are unicellular. Their mode of nutrition is saprotrophic but very few of them are human parasites. Common fungal human diseases are Ring Worm, Athlete's foot, histoplasmosis, candidia (thrash) etc.

#### Ring Worm

Ring Worm is a skin disease caused by fungus. The disease is spread by spores of the fungus which are passed from one individual to another by personal contact or by contact with clothing since the fungus can grow on clothing or other personal objects. Hyphae of the fungus penetrate the outer layers of the skin and grow in the normal way. The red patch as it spreads, causes intense itching. As the fungus grows, the center loses its colour to normal leaving a circular red patch which is darker at the edge. The name 'ring worm' is given because of this appearance.

#### Athlete's Foot

Athlete's foot is also a fungal disease. It is sort of ringworm of the foot. Fungus attacks soft skin between the toes and in bad cases spreads over the whole foot. The skin peels off leaving very sore patches.

Infected floors and mats spread the problem.

## 20.9 Some common Parasitic Worms

Some common parasitic worms are round worms, thread worms, liver fluke and tapeworms.

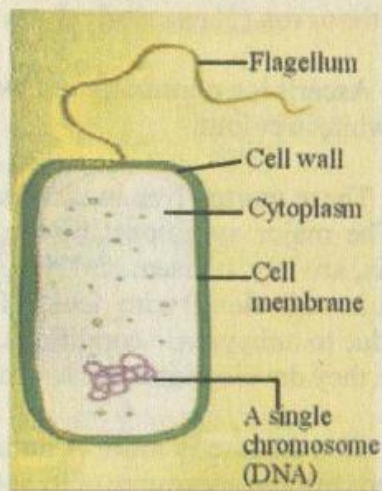


Fig 20.9 Structure of Bacterium

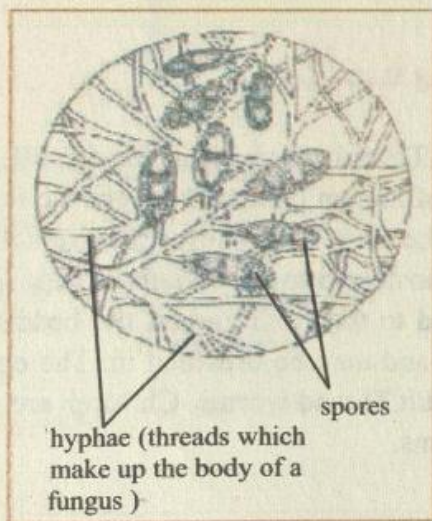


Fig. 20.10 Fungus which causes Ring

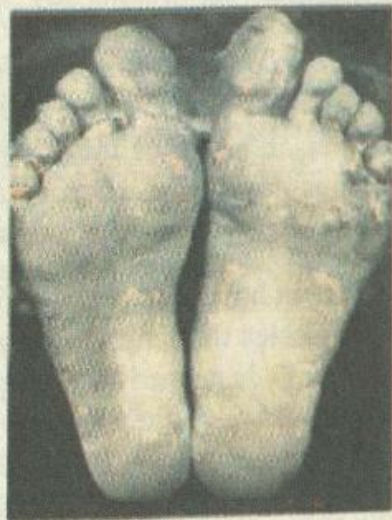


Fig. 20.11 Athlete's Foot



## Roundworms (Nematodes)

Ascaris is a common roundworm. It is 20-30 cm long and is pinkish white in colour.

These worms live in the small intestine of man and move freely. The major symptoms of the disease are abdominal pain, dyspepsia, anxiety, nausea, and coughing. The eggs of Ascaris are excreted in soil along with feces. These eggs can enter another person, due to unhygienic conditions. When these eggs reach small intestine, they develop into new worms and cause disease.

This disease is more common in children as compared to adults and children are source of its spread.

In this disease, as the worms feed on the food of the patient, that is why patient suffers from malnutrition.



## Thread Worms

Thread worms are very small only  $\frac{1}{2}$  inch long. Both male and female worms live in the colon of human beings. At night the female descends the colon and lays her eggs in the folds of skin about the anus. This causes intense itching, if the anus is scratched, the eggs stick to the fingers and thus transferred to the mouth or deposited on cutlery and household utensils. The eggs also become attached to the clothing and the bedding. When these articles are shaken, the eggs are dispersed in the air and may be breathed in. The eggs pass to the stomach and to the large intestine and develop into adult Thread worms. Children are mainly affected by these worms. Drugs can be given to get rid of worms.

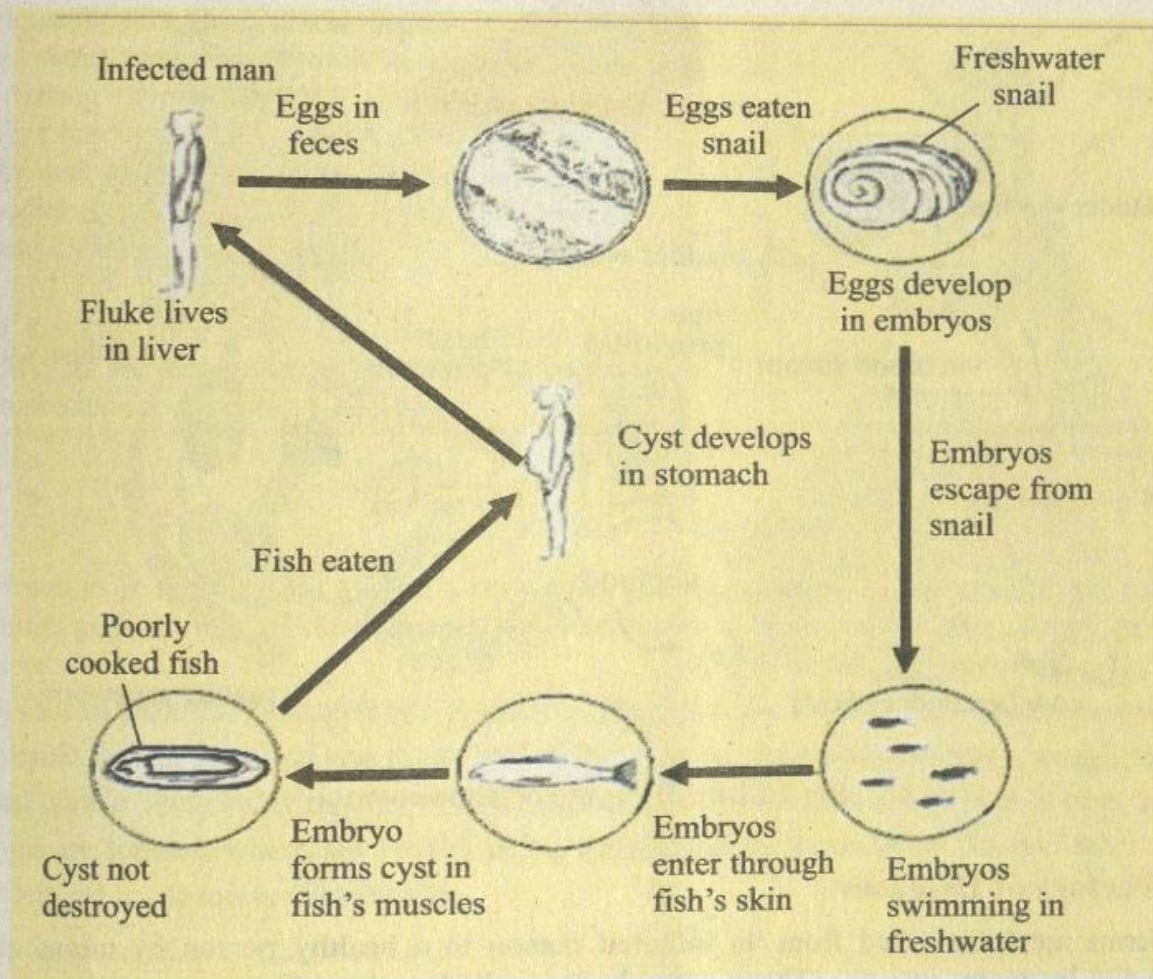
## Liver Fluke (Platyhelminthes)

The fluke are flat worms. They are the parasites of both man and animal. All flukes require at least two hosts to complete their life cycle. One of the fluke is liver fluke. It lives in and feeds in the liver of the human beings, where it causes much damage. The eggs of the fluke pass out in the faeces of infected person and thus they may come to the freshwater. Snails living in the freshwater eat the eggs. The eggs develop and form larva in the snails. The larva develops into small creature with a tail. At this stage they leave the snail and swim into water and seek a fresh host.

Their next host is freshwater fish. The embryos penetrate the skin and enter the muscles of the fish. In the muscles the embryo form a hard protective layer and become cysts. These cysts are very hard and are only destroyed by a thorough cooking of the fish. When partially cooked fish is eaten by man, the cysts arrive in the stomach and there they develop. From the stomach the parasites pass to the liver, where they grow to adult flukes. The adult flukes are both male and female, they come together and fertile eggs are produced and the cycle is repeated (Fig 20.13).



Drugs for the treatment are available but the best way is to improve sanitation.



**Fig. 20.13 Life cycle of Liver Fluke**

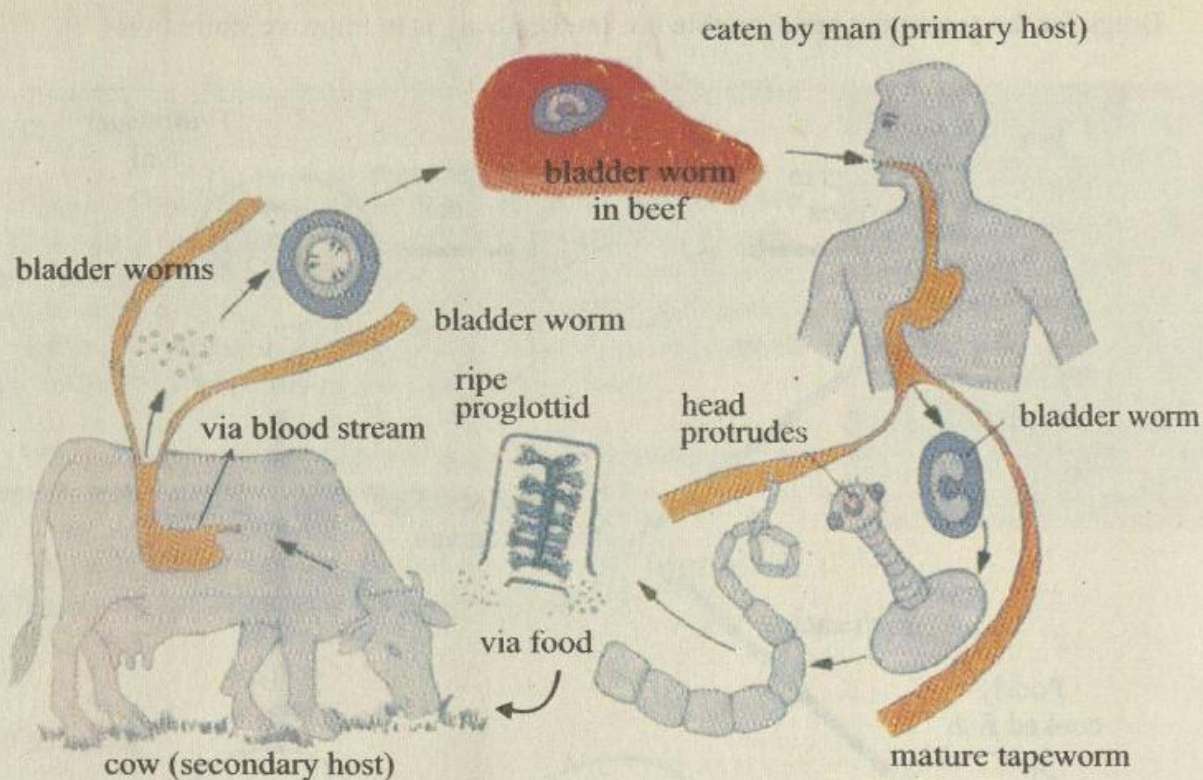
### Tapeworms (*Taenia solium*)

Flat worms are largest organisms to parasitize human beings. They are called flat worms because of their flattened bodies. All tapeworms are parasites and require at least two hosts to complete their life cycle.

Tapeworms have a small head on which suckers and sometimes hooks are present to attach them to their host's intestine. Their length varies from few centimeters to 10 meters and their body is made of segments called **proglottids**. They are hermaphrodite i.e. each proglottid has both sexes.

The life cycle of tapeworm involves two hosts. Primary host is the one in which the adult tapeworm lives and reproduces. And secondary host is an animal, which is eaten by the primary host. For example beef tape worm's primary host are humans and secondary host is cattle. If the sewage disposal conditions are not proper, tape worm eggs may be eaten by a cow while grazing. Because of the digestive juice of cow in the gut, larvae come out of the eggs which then find their way into the muscular tissues. There they remain unchanged for several years. If the partially cooked cow meat of infested cow is eaten by humans the larvae are activated by digestive juices, where they manage to attach the intestinal wall with their suckers or hooks. There the larvae develop into adult tapeworms. After fertilization sex organs disappear and are replaced by thousands of microscopic proglottids. At this stage proglottids drop from the tape worm and pass out of the host's body with faeces (Fig 20.14).

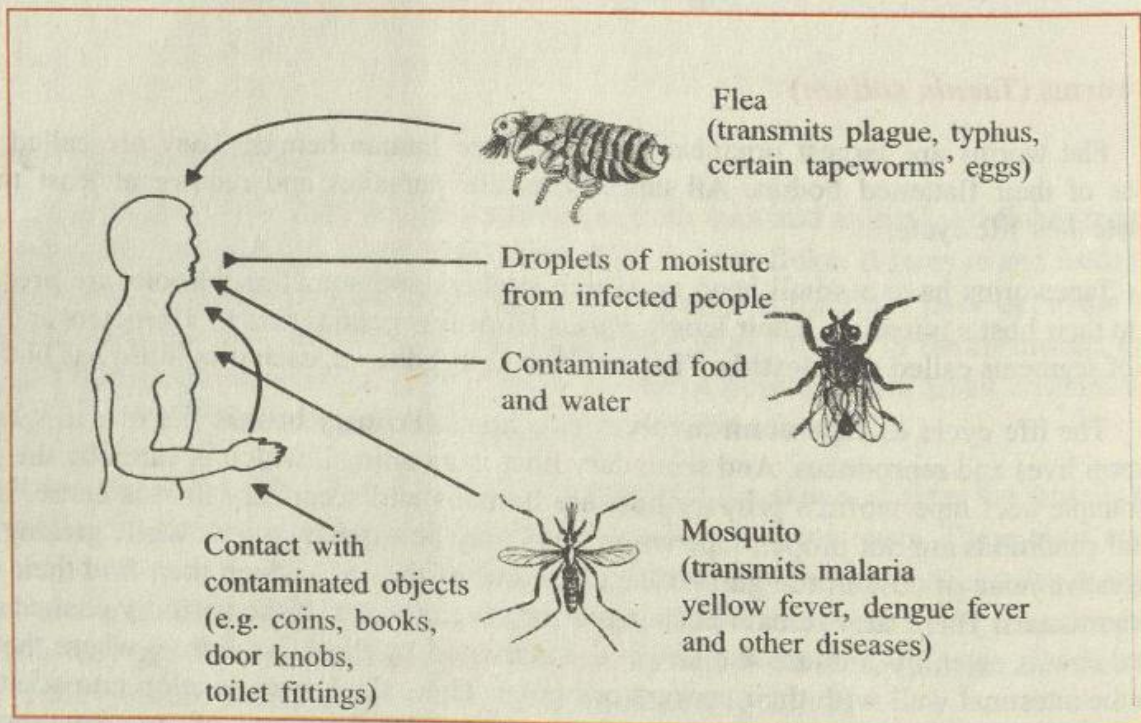




**Fig 20.14 Life cycle of Tapeworm**

### 20.8.1 Vectors of Diseases

Germes are transmitted from an infected person to a healthy person by means of animals (for example; by many insects). These animals are called vectors. Common vectors are housefly, sand fly, mosquitoes, fleas, cockroaches, dogs, mice etc. (Fig 20.15)



**Fig. 20.15 Diagram summarizing the spread of infections**



## Housefly as a Vector of disease

Housefly is a mechanical vector. It feeds on decaying matter and dung which is rich source of germs causing typhoid fever, typhus, cholera, dysentery, tuberculosis and anthrax along with some tapeworm and roundworm eggs. As flies feed their feet, bodies and digestive system becomes contaminated with germs and eggs.

If the flies then settle on human food, the germs and eggs are deposited on the food. By eating this contaminated food persons become ill.

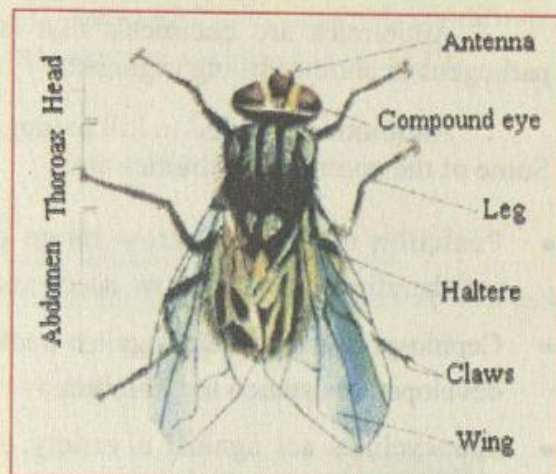


Fig. 20.16 Housefly

## Mosquitoes as Vectors

Mosquito is a biological vector because the pathogen which is responsible for causing the disease under goes a cycle of development in it. Mosquito is a vector for transmitting malaria and yellow fever.

In case of malaria, pathogen is a protozoan *Plasmodium*. *Plasmodium* under goes two stages in its life cycle, one in man and one in the mosquito. In man, the parasite enters through the bite of an infected female *Anopheles* mosquito. One stage of its life cycle is completed in man, as a result gametocytes are formed, which are sucked along with blood by a mosquito. Second stage of its life cycle is complete in mosquito (Fig 20.17).

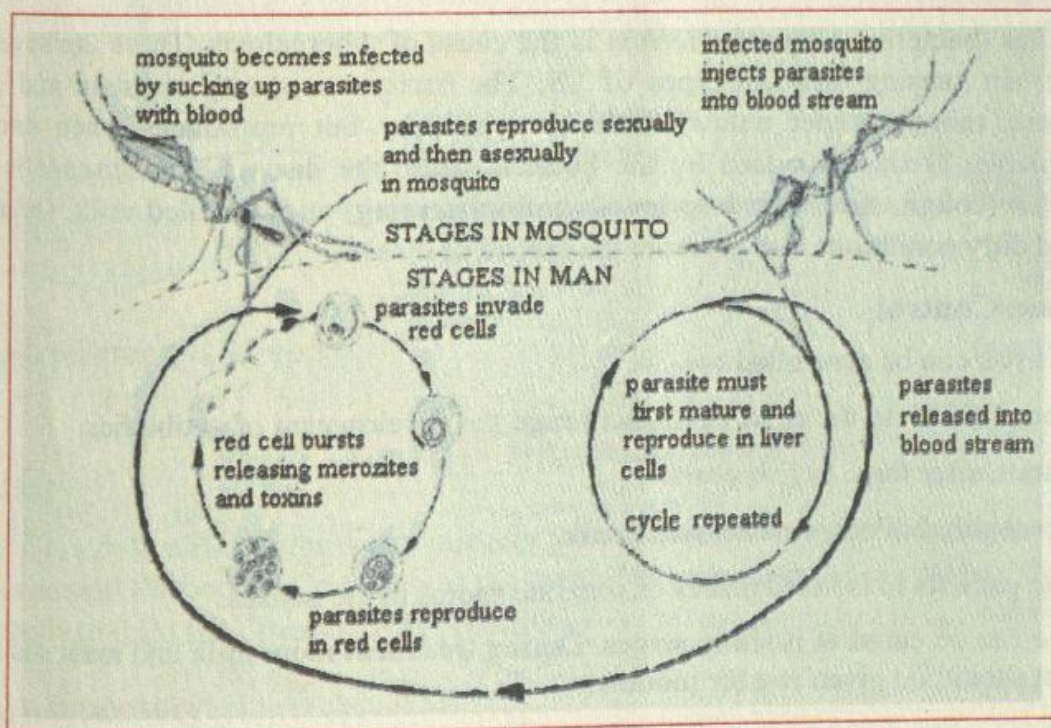


Fig. 20.17 Life cycle of *Plasmodium*

The mosquito in its life cycle is an intermediary host. Without this intermediary stage, the disease would not be passed from patient to healthy person.

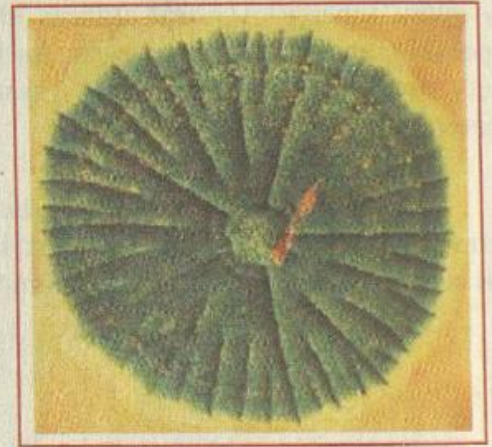


## ANTIBIOTICS AND THEIR IMPORTANCE

Antibiotics are chemicals that are extracted from one living organism and which destroy pathogens in another living organism.

Antibiotics are used to kill pathogenic bacteria but they do not harm viruses. Some of the common antibiotics are;

- Penicillin attacks a narrow range of bacteria and are therefore called narrow spectrum antibiotics.
- Cephalosporins are useful against bacteria which have developed resistance to penicillin.
- Tetracyclines act against a variety of bacteria. They are broad spectrum antibiotics.
- Erythromycins are useful against bacteria which have developed resistance to penicillin.



**Fig.20.18 *Penicillium chrysogenum***

## 20.9 Some Common Diseases

### Tuberculosis (TB)

Tuberculosis is worldwide but is most common in tropical areas. Tuberculosis takes a long time to develop but depends mainly upon the health and state of the people. Most common TB is of the lungs, apart from TB of intestine, bones etc.

### Causative Organisms

A bacillus (bacterium) *Mycobacterium* is the cause of tuberculosis. There are several species of *Mycobacterium* causing different types of TB. The bacterium is very resistant and can remain alive for several months under unfavourable circumstances but reproduces when circumstances become favourable. Toxins produced by the bacteria cause the disease. The disease is spread by droplet infection (cough, sneezing, deep breath and by spitting) and unboiled milk. Over-crowding and humid and dirty conditions also promote the spread of disease.

### Treatment and Control

The disease can be controlled by;

- Vaccination of BCG to the children to encourage the development of antibodies.
- Revaccination after three to five years.
- Use of thoroughly boiled or pasteurized milk.
- By keeping patients in isolated places or separate rooms in the houses.

Disease can be cured in its early stages. During treatment more milk and meat should be taken and the patient should be given rest for months.

### Cholera

Cholera is mainly found in Asia and commonly spreads in humid conditions. Disease begins with fever, diarrhoea and vomiting, accompanied by severe abdominal pain. Severe attacks result in dehydration and death of the patient.

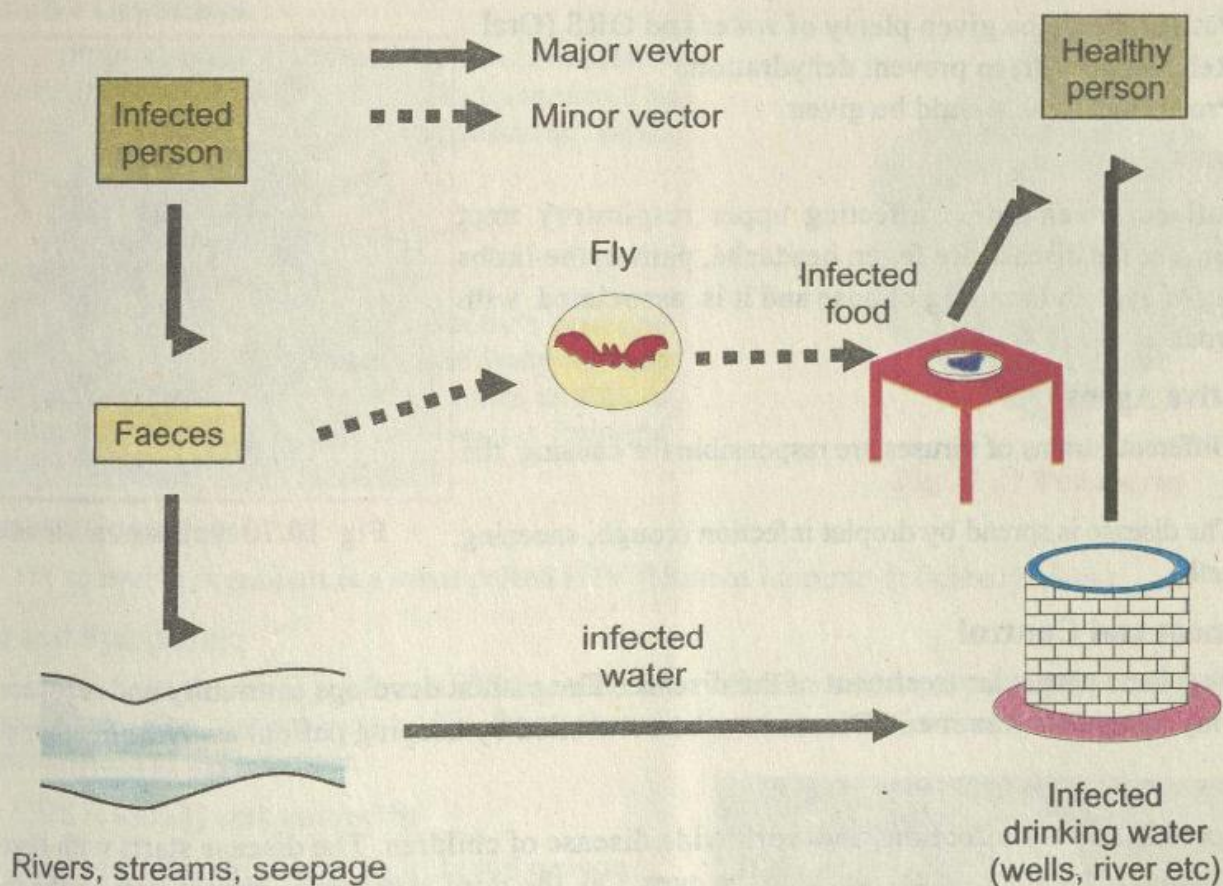


## Causative Organism

Cholera is caused by a comma-shaped bacterium called *Vibrio cholera* with a flagellum which enables it to swim in water. *Vibrio Cholera* is ono-caplulated and cannot withstand dry condition. It is water born. The disease is spread by the use of contaminated water and food (Fig 20.19).

## Control over the Disease

- By the use of boiled or chlorinated water.
- By keeping our food covered to avoid its contamination.
- By injecting cholera vaccine which gives an active artificial immunity for six month.
- By keeping infected persons in isolated places as the bacteria are transmitted by flies as well as by water.
- Good sanitation is required to prevent the contamination of water.



**Fig 20.19 Disease cycle of cholera**

## Treatment

Saline solution is continuously injected into vein of patient to maintain the body fluid balance. This does not kill the bacteria but enables the patient to overcome the effects of dehydration and allow his own body to fight the disease. Drugs (antibiotics) are also given to kill the bacteria.

## Bacillary Dysentery

Bacillary dysentery is a food-born disease. Symptom of the disease is severe pain in the lower abdomen. It is followed by diarrhoea and fever. There is appearance of mucous and blood (in the case of severe attack) in the stools.



### Causative Organism

Bacillary dysentery is caused by rod-shaped (bacilli) bacteria. The bacteria are motile and are found in the faeces of patients in large numbers. The disease is spread by the use of contaminated food and from unwashed hands after using lavatory.

### Control over Disease

- By protecting cooked and uncooked food from houseflies.
- By careful washing of hands after using toilet.
- By adopting proper methods of sanitation to prevent flies from sitting on human faeces and breed there.

### Treatment

- The patient should take rest and eat no solid food for a day or two.
- Patient should be given plenty of water and ORS (Oral Rehydrate Salt) to prevent dehydration.
- Proper medicine should be given.

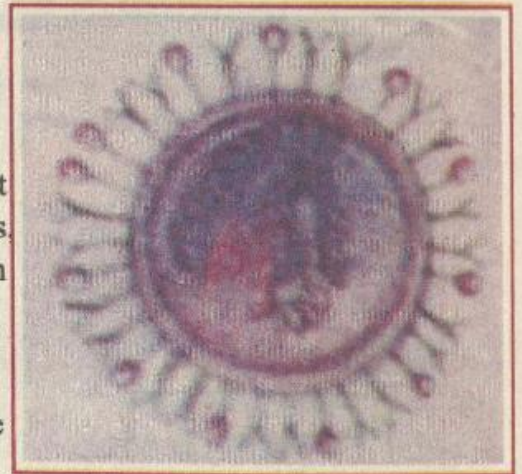
### Influenza

Influenza is an illness affecting upper respiratory tract. Symptoms of the disease are fever, headache, pain in the limbs, watering of eyes and running of nose and it is associated with sore throat.

### Causative Agent

Different strains of viruses are responsible for causing the disease.

The disease is spread by droplet infection (cough, sneezing, and breath).



**Fig 20.20 Influenza Virus**

### Treatment and Control

There is no particular treatment of the disease. The patient develops immunity and recovers. Rest is the only immediate treatment. Disease can be controlled by keeping patient away from other people.

### Measles

Measles is a very infectious and worldwide disease of children. The disease starts with fever with cold, cough and a watery discharge from the eyes. On the third day rashes appear first on the face and then spread over the whole body.

### Causative Organism

The causative organism is a virus, which is air born and is inhaled in droplets. The disease spreads through the discharge from eyes and nose, which becomes air-born and spreads rapidly.

### Treatment and Control

There is no specific treatment. Child develops immunity and the signs and symptoms of the disease disappear after seven days. The child should be given plenty of drink especially milk.

It is difficult to control the disease because it is highly infectious as the patient becomes infectious about 2 days before the symptom of the disease develop.



## Poliomyelitis

Poliomyelitis is most common among the children but young and old people can also become its victims.

It begins slowly. The sufferer has very high fever, headache, nausea, fits and stiffness of limbs. In severe cases, the virus attacks the nerve fibers of the spinal cord causing paralysis of the limbs and muscles of the respiratory tract, sometime proving fatal, apart from permanent disabilities.

### Treatment and Control

There are two polio vaccines; sabin vaccine and salk vaccine. Sabin vaccine is more common and is given orally in the form of drops. Two or three drops are given to infants during their first year which provides life long protection against polio by developing active immunity against it. Salk vaccine is injected in to the body but it is not being practiced in our country.

### Causative Organism

Poliomyelitis is caused by virus, which is transmitted by infected water. It is also transmitted by droplet infection during coughing and sneezing, of the patient.

## AIDS (Acquired Immune Deficiency Syndrome)

AIDS is a disease in which body's immune system, the system which protects our body against infections, is destroyed. The body becomes unable to protect itself against many other diseases i.e. immune deficiency develops.

### Causative Organism

The causative organism is a virus called HIV (Human Immune deficiency Virus).

### Signs and Symptoms

The word syndrome is used in AIDS because it is a disease with many symptoms occurring at the same time. The patient may suffer from chronic fever, severe diarrhoea lasting for months, pneumonia etc. and even cancer.

AIDS is usually transmitted by

- Sexual relationship with an infected person.
- Blood transfusion from infected person.
- By sharing contaminated injection needles. For example when drug addicts share their used syringes.
- By using contaminated razors, surgical and dental instruments etc.
- Virus may pass from the infected mother to the foetus during pregnancy.

### Prevention and Control

Aids can be prevented by talking following measures

- By keeping to one's own sex partner.
- By avoiding drug abuse as drug addicts share hypodermic needles.
- By using disposable syringe.

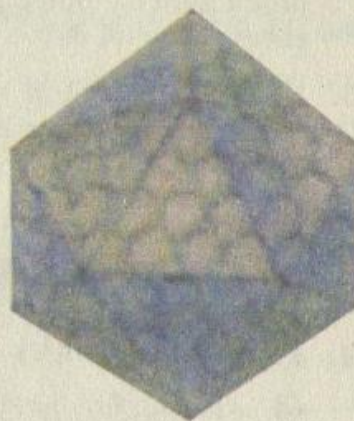


Fig 20.21 Polio virus

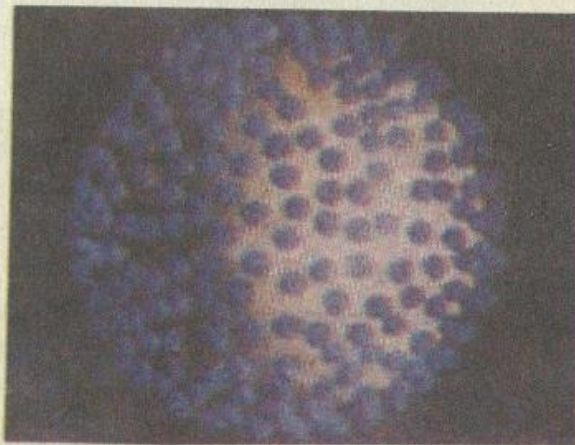


Fig. 20.22 HIV



- By sterilizing the medical equipment before examining the patients.
- By avoiding the sharing of instruments that cause lesion and be contaminated with blood e.g. toothbrushes and razors.
- By using carefully sterilized surgical instruments / equipments.

## KEY POINTS

1. Genetic engineering is the manipulation of genes at will, and has great application in agriculture, chemical, drug industries and medicine.
2. Fermentation process carried on by bacteria and fungi is useful in the production of food e.g. yogurt, bread, cheese, alcohol etc.
3. Bacteria are helpful in improving soil fertility by fixing atmospheric nitrogen.
4. Biology is playing its role in the economic development of man.
5. Dairy, poultry, forestry, agriculture and many other related fields, are being improved.
6. Microorganism such as viruses, certain bacteria, fungi and protozoan are pathogenic and are responsible for causing various diseases.
7. Certain worms such as roundworms, flat worms thread worms and liver flukes are parasites and cause different diseases in man.

## EXERCISE

### 1. Fill in the Blanks

- (i) Genetic Engineering is a technique used to transfer Genes from one \_\_\_\_\_ to another.
- (ii) Most bacteria are saprophytic decomposes, meaning that they \_\_\_\_\_.
- (iii) \_\_\_\_\_ is an important component of proteins.
- (iv) *Ascaris* is a \_\_\_\_\_ worm, which lives in \_\_\_\_\_.
- (v) Mean of transmission of a pathogen from an infected person to a healthy person is called \_\_\_\_\_.
- (vi) Honeybees are \_\_\_\_\_ consisting of queen, drones and workers.
- (vii) Forestry is the business of cultivating \_\_\_\_\_.
- (viii) Over-crowded, humid and dirt conditions promote the spread of \_\_\_\_\_.
- (ix) Mosquito in the life cycle of plasmodium is an \_\_\_\_\_ host.
- (x) Sericulture is the production of silk by the activity of \_\_\_\_\_.

### 2. Write whether the statement is "true" or "false". Correct the statement if it is false.

- (i) Thyroxine is a hormone which controls the amount of sugar in the blood.
- (ii) Role of biotechnology in the production of food is based on the process of decomposition.
- (iii) Human population grows when more people die each year than are born.
- (iv) Life cycle of tapeworm involves three hosts.
- (v) Causative organism of AIDS is a bacterium.
- (vi) Contamination of the environment with waste products and other impurities is called pollution.
- (vii) BOD is a measure of water pollution level due to sewage and other organic matter.
- (viii) People who can not make insulin suffer from Diabetes mellitus.

### 2. Each question is followed by four options. Encircle the correct answer.



(i) To which group(s) microorganisms which bring about Nitrogen fixation in root nodules of Legumes belong to?

- (a) Protozoa and bacteria
- (b) Fungi and bacteria
- (c) Bacteria
- (d) Fungi

(ii) Which organism transmits parasites from one host to another?

- (a) Bacterium      (e) Pathogen
- (b) Vector          (d) Virus

(iii) Role of biotechnology in the production of food is based on

- (a) Respiration
- (b) Decomposition
- (c) Digestion
- (d) Fermentation

(iv) Mutualism is an association between two individual in which;

- (a) One partner gets benefit and other is harmed
- (b) One partner gets benefit and other is neither harmed nor get benefit
- (c) Both partner get benefit
- (d) Both are harmed

(v) Which form of drug abuse involves most risk of infection with the HIV (AIDS) virus.

- (a) Cigarette smoking
- (b) Using alcohol
- (c) Injection of heroine
- (d) Taking too many aspirin

**4. Name the organism which;**

(a) Causes malaria

(b) Spreads malaria from person to person

(c) Causes AIDS

(d) Is responsible for cholera

(e) Causes Ring Worm

**5. Which of the following terms A-E are associated with a-e:**

- A. Sulfur dioxide      D. Pollution
- B. Ozone layer        E. Pollutants
- C. Sewage

(a) The process by which harmful substances are added to the environment.

(b) Waste organic matter that causes water pollution.

(c) Exhaust of motor vehicles releases these harmful substances into the atmosphere.

(d) This acts as a shield preventing too much Ultra Violet rays from reaching the earth.

(e) This gas is produced by the burning of low-grade oil and coal.

**6. How does recycling of used materials help to conserve the Environment?**

**7. Write a note on air pollution.**

**8. What is green-house effect?**

**9. What is the role of biotechnology in food production?**

**10. Write a note on nitrogen fixation.**

**11. State the importance of antibiotics.**

**12. Discuss the following:**

- (a) AIDS
- (b) Cholera
- (c) Measles



Read it after life cycle of flowering plant on page 78 (before Figure 16.9).

### Male Gametophyte

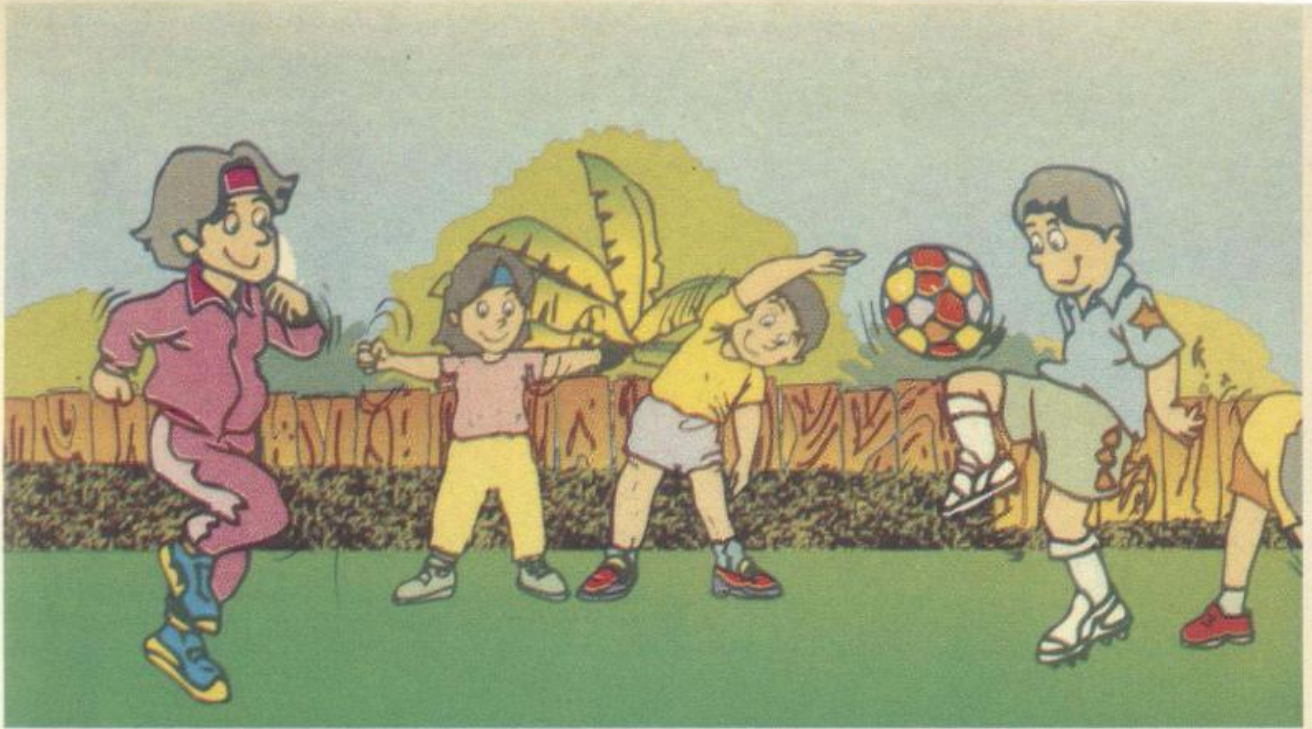
The microspores are produced in the pollen sacs of anther of stamen, by meiosis. These microspores mature into pollen grains. The pollen grain germinates, after it falls on the stigma of the carpel. Pollen grain has a generative nucleus, and a tube nucleus. Generative nucleus divides to form two sperm nuclei. Tube nucleus forms a long pollen tube, in which two sperms move. This structure, having a pollen tube with two sperms and one tube nucleus is the male gametophyte.

### Female Gametophyte

The ovary of carpel may have one or more ovules. Ovules is a megasporangium with outer integuments which have an opening called micropyle. The megaspores are produced by meiosis in the ovule. Out of four megaspores formed, only one gives rise to female gametophyte. The megaspore under goes three mitotic divisions, which result in 8 - celled female gametophyte. Three of these cells are present at one pole and the three others at the opposite pole which are, the egg, and two synergids or help cells. The central cell of gametophyte contains two polar nuclei.







Exercise is essential for the body; it makes us feel good all through the day.



Clip your nails on time so that dust does not get stuck in them.  
Also, wash your hands and feet regularly.

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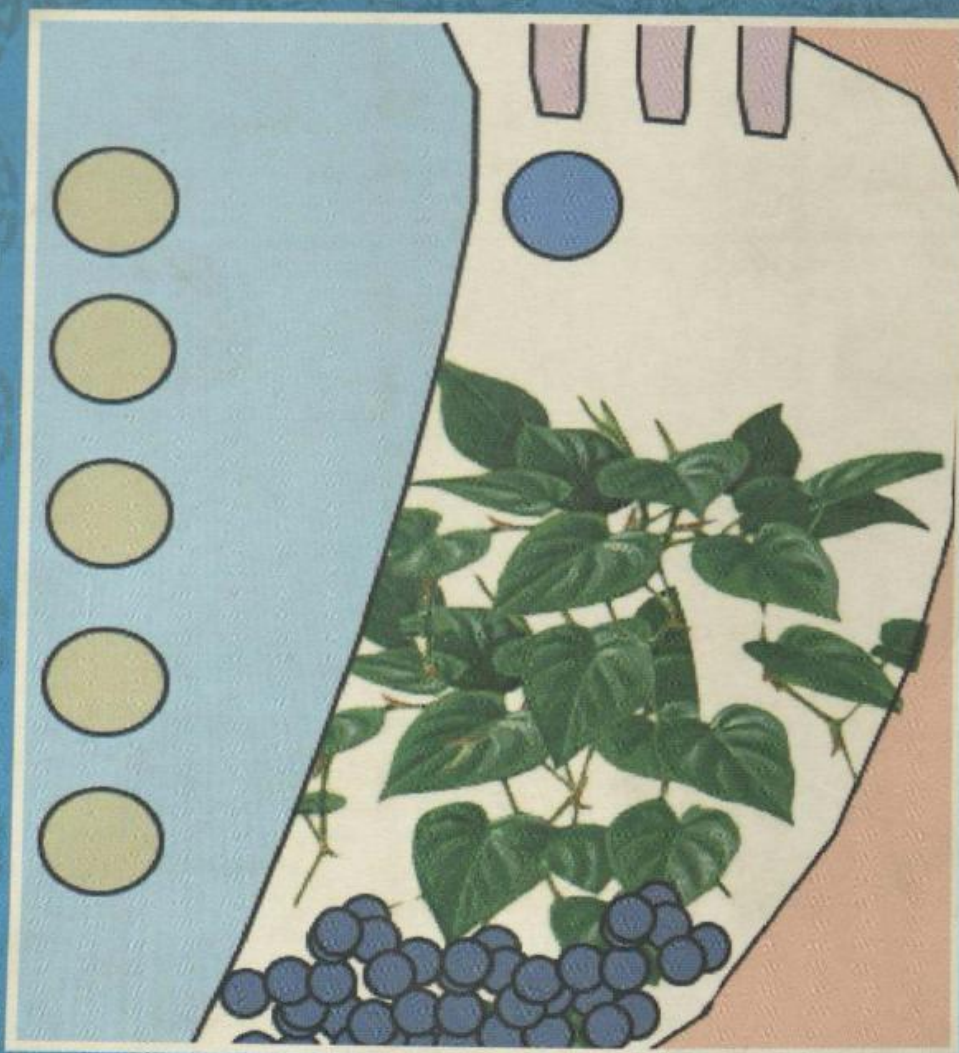


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